Astronomy and Astro-Physics.

VOL. XII, No. 10. DECEMBER, 1893. WHOLE No. 120.

General Astronomy.

ON A PRACTICAL METHOD OF DETERMINING DOUBLE STAR ORBITS BY A GRAPHICAL PROCESS, AND ON THE ELEMENTS ☊ AND λ.*

T. J. J. SEE.

In the present paper we propose to discuss briefly the methods of determining double star orbits, and to suggest certain modifications in the elements ☊ and λ ($= \pi -$ ☊), which seem desirable for the sake of uniformity. Since Savary's first attempt to find the orbit of a double star in 1827,† a number of other astronomers have proposed methods of great theoretical elegance and mathematical rigor for finding the orbits of double stars when the observations suffice to fix the apparent ellipse. The methods most deserving of mention are those of Encke,‡ Herschel,§ Thiele, Klinkerfues,‖ Kowalsky,¶ and Seeliger.**

As most of these methods are satisfactory theoretically, we shall here confine our attention to the practical work of determining orbits from data now furnished by observation, and shall suggest a short method which will give good practical results without lengthy calculations involving minute corrections not warranted by the present state of double star astronomy.

Sir John Herschel long ago introduced the use of graphical interpolating curves as a means of freeing the angles and distances from the accidental errors of observation. One axis was made to represent the time, the other the angle or distance.

Now it is evident that if the angles or distances changed slowly and uniformly with respect to the time, the curve of interpolation would flow smoothly and the flexure would be gradual. But it is well known that the radius vector of the companion describes

* Read before the Congress of Astronomy and Astro-Physics, Chicago, Aug. 23, 1893.

† See the *Connaissance des Temps*, 1830, for the method in full.

‡ *Berliner Jahrbuch*, 1832.

§ Memoirs Royal Astronomical Society, Vol. V.

‖ *Astr. Nachr.*, Vol. XLVII, p. 353, or Klinkerfues' *Theoretische Astronomie*, 1871.

¶ See Glasenapp's paper in *Monthly Notices*, March, 1889.

** Dr. Schorr's *Inaugural Dissertation*, München, 1889.

equal areas in equal times, and as the apparent distances in different parts of the orbit are, in many systems, very unequal (owing to the various eccentricities and inclinations), it follows that the angles and distances will frequently change at very unequal rates with respect to the time. And as the rate of change is unknown there is no means of knowing what the curvature will be at a given point; so that the course of the graphical interpolation becomes uncertain, and the drawing of the curve is altogether a matter of judgment.

Hence, although Herschel may have regarded the graphical interpolating curves as advantageous devices at a time when the systems showed very little motion (and hence the *curvature* was not so uncertain as where the motion is great and unequal), it is very doubtful whether he would commend this method of interpolation at the present time.

We may also observe that the uncertainty as to the course of the true interpolating curve enters with full effect into the graphical normal places, and if we base the orbit on points thus determined the resulting path will often show a systematic deviation from the true ellipse. Hence such correction of observations is not only of doubtful value, but likely to lead to systematic errors which cannot be eliminated from the final result. If, on the other hand, we plat the observations directly (corrected only for the precession, if that is sensible), we shall obtain a series of points through which the trial ellipse must pass as a sort of interpolating curve, following the best observations. By means of an ellipsograph this apparent orbit can be drawn with geometrical precision and made to satisfy the observed distances and at the same time conform to the law of areas.

This trial ellipse is an interpolating curve which meets the conditions of the problem admirably, while it also renders the agreement of the observations with the proposed orbit singularly conspicuous to the eye. Moreover it avoids in a high degree the systematic errors incidental to graphical interpolation when the motion in angle and distance varies at different points of the orbit; hence when the trial ellipse has been carefully drawn it furnishes a suitable basis for the deduction of the true orbit by graphical methods such as those of Klinkerfues* and Ball.†

The great problem in double star astronomy is to find the apparent orbit, since when the apparent orbit is once found, there is no difficulty in finding the true orbit by means of formulæ based

* *Theoretische Astronomie*, p. 392.
† *English Mechanic*, April 21, 1893.

upon the law of gravitation. It is assumed in the graphical method sketched above that the apparent orbit is drawn on a scale sufficiently large to prevent sensible error in the graphical work, and this can be secured by adopting a scale of convenient size, making the major axis of the apparent ellipse from 6 to 12 inches in length. The value of the elements will depend upon the agreement of the apparent ellipse with the observations. When this agreement is satisfactory, and the ellipse is geometrically perfect, the resulting elements will have the required degree of precision.

For a long time it has been customary to test the accuracy of double-star orbits by comparing the computed with the observed places, and to estimate the value of an orbit mainly by the residuals of position angle. Mr. Burnham's great practical experience with the micrometer has shown that distances (especially in case of close pairs) are quite as trustworthy as angles, and the method of finding an orbit solely by means of position-angles has been repeatedly discredited by absured results of computers who discard the measures of distance. The belief prevailing among astronomers early in this century that distances were necessarily less accurate than angles was probably due, in part at least, to the inaccuracy of the older micrometers, and to the circumstance that the older observers had measured chiefly angles. But since the epoch-making work of the Struves, Dembowski and Burnham, there is, of course, not the least foundation for this antiquated tradition. That distances should be given more weight in the determination of orbits than has been customary hitherto, is sufficiently established by the work of Mr. Burnham on numerous stars and by the researches of Otto Struve on the orbit of 42 Comæ Berenices (*M. N.* vol. XXXV, p. 370), which depends almost solely upon distances. We also observe that when the orbit is highly inclined upon our visual ray, distances must necessarily form the basis for the orbit, since the measures of position-angles are practically worthless, owing to the slow change of the angle and the wide range of errors of observation.

In general it is evident that the orbit should be based upon both angles and distances, and it is of the utmost importance that the apparent orbit should be compared directly with the platted measures, so that the representation of the observations can be seen at a glance. This is the line of procedure adopted in the graphical method, which is therefore the logical process of finding the true elements of binaries.

Some astronomers will doubtless consider that an orbit deduced by the method of Least Squares is much to be preferred to one deduced by the graphical method sketched above. That this is not the case with most systems as now known will be evident on recalling the existence in double-star measures of conspicuous systematic errors, which do not follow the laws of chance, and therefore can not be eliminated by the method of Least Squares. We should also remember that the theory of probability does not require the positive and negative residuals to vanish except when all *mistakes* are excluded, and the number of observations is increased beyond limit. Since in any actual case it is practically certain that these conditions are not fulfilled, even approximately, it is evidently of doubtful value to apply the method of Least Squares, except possibly in exceptional cases where the observations are very complete and accordant.

We are not here questioning the soundness of the method of Least Squares (for it is founded upon the philosophical principles of probability as laid down by Laplace and Gauss), but only doubting the propriety of applying the method where the conditions are wanting which underly the theory of Least Squares.

In the last 20 years frequent application has been made of Least Squares in double star astronomy, and in numerous cases we need only plat the observations with the resulting orbit to show the entire absurdity of the results obtained. Mr. Burnham has frequently called attention to the untrustworthy character of orbits of this nature, where the measures are few and scattering and of doubtful value; and we shall here merely remark that under such circumstances it is undoubtedly better not to apply the method of Least Squares at all. And in any event we certainly must not expect that the algebraic sum of the residuals will vanish. If the method of Least Squares can be advantageously used in research on double star orbits, it will be in cases where the number of observations is large and the measures are practically free from systematic error. The trial ellipse secures all that is sought by the method of least squares, and, in part at least, avoids the effects of systematic errors; while it also conveys a just conception of the uncertainty necessarily attending double star elements in the present state of our knowledge. On the other hand the small probably errors obtained by the method of Least Squares are likely to convey the impression of much greater accuracy than is possible with the rough data now available. Lastly, we may add that the simple graphical method is a great saving of time and labor, compared with the tedious

method of a Least Square adjustment, which involves the formation and solution of a large number of normal equations. This graphical method was introduced into modern double star astronomy by Mr. S. W. Burnham, who has adopted it as the simplest and most practical means of finding orbits; but substantially the same method of representing measures was employed early in this century by William Struve.* It is somewhat remarkable that the most direct and practical of all methods should have been so much overlooked during the last half century, and we can only attribute this oversight to the undue importance assigned to the use of position-angles and to the adjustment of residuals by the method of Least Squares.

We shall now exhibit some of the orbits which we have recently obtained by the method sketched above, and from the agreement of the observations with the resulting orbits we shall be able to see what margin of uncertainty still remains in the elements of double stars.

[The speaker here exhibited the apparent orbits of γ Virginis, η Cassiopeiæ, α Canis Majoris, 70 Ophiuchi, ζ Cancri, η Coronæ Borealis, ξ Scorpii, Σ 3062, Σ 2173, 42 Comæ Berenices, β Delphini, ζ Herculis, ξ Ursæ Majoris, γ Coronæ Borealis, ω Leonis, γ Coronæ Australis, Σ 3121, μ^1 Herculis, μ^2 Böotis, and δ Equulei].

From the drawings which have been presented we see what degree of accuracy has been attained in double star work, and it is now evident that the graphical method is not only accurate enough for the finest requirements of modern measures, but the simplest and most logical method, and one which will therefore commend itself to working astronomers.

We shall now discuss the elements ☊ and λ. It is well known that the formulæ for determining the elements of the orbits of double stars do not enable us to distinguish between ascending and descending node.

Now as there are two nodes 180° apart, it follows that one of these nodes must necessarily fall between 0° and 180°; accordingly, this node will be taken as the ascending node,§ and we shall reckon λ and u (argument of the latitude) from this node in the direction of the motion, from 0° to 360°. By this method of reckoning ☊ and λ and u, it will be easy to find the true anoma-

* Mensuræ Micrometricæ, last plate.

† Spectroscopic application of Döppler's principle will eventually enable us to decide which is really the ascending node, where the companion moves towards the Earth relative to the central star.

lies when the arguments of the latitude have been computed; for we shall have $v = u - \lambda$, both for direct and retrograde motion.

The above method of reckoning ☊ and λ will be very convenient for laying down the apparent orbit of a double star, from the elements, by the graphical method recently discovered and published in the ASTRONOMY AND ASTRO-PHYSICS (August, 1893), and it will, above all, bring consistency and uniformity where confusion now exists.

We believe that any slight inconvenience that may arise in case of analytical formulæ used by some computers can be easily overcome; but even if this be impossible, it will be easy to deduce the elements as formerly, and then to transform them into the system here suggested. The advantages of this way of reckoning for graphical purposes and the uniformity thus secured must be regarded as a sufficient defense of the innovation thus introduced.

THE UNIVERSITY OF CHICAGO,
1893, August 19.

NOTE:—The reader will see from the accompanying orbit of γ Virginis how the practical method above suggested is applied. The observations were taken from original sources, and include all the measures of any value hitherto published. From this mass of data, we formed means (usually yearly) based upon the measures of the best observers—such as Struve, O. Struve, Mädler, Secchi, Dawes, Dembowski, Englemann, Hall, Schiaparelli, Burnham, Perrotin, etc. These means were platted directly, and the accompanying orbit drawn by means of an ellipsograph.

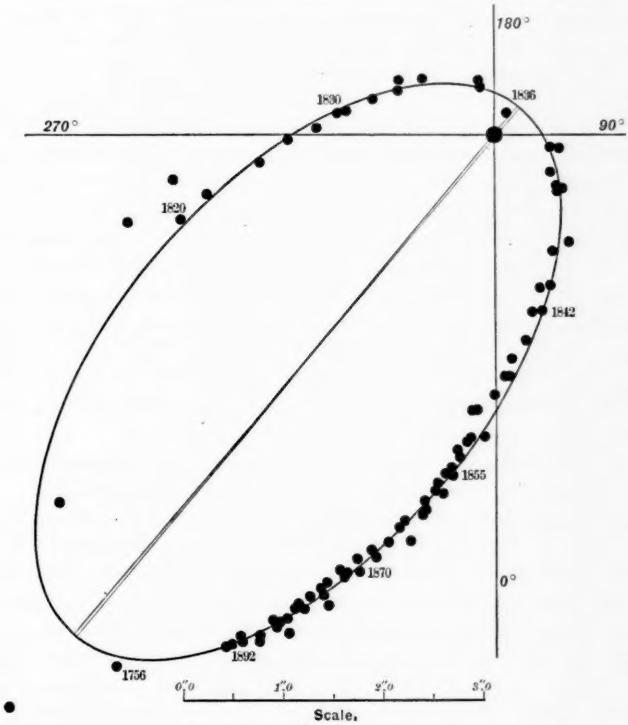
The elements of γ Virginis are:

$$
\begin{aligned}
P &= 192.07 \text{ years.} \\
T &= 1836\ 51 \\
e &= 0.895 \\
a &= 4''.1436 \\
i &= 34^\circ.12 \\
\Omega &= 54^\circ.90 \\
\lambda &= 274^\circ.23 \\
u &= -\,1^\circ.87422
\end{aligned}
$$

Apparent Orbit:

Length of major axis	$= 6''.86$
Length of minor axis	$= 3''.65$
Angle of major axis	$= 139^\circ.5$
Angle of periastron	$= 139^\circ.8$
Distance of star from centre	$= 3''.07$

The system of γ Virginis is remarkable for the great eccentricity of the orbit and for the equality of the components. As the parallax of the system has never been determined, we can not



γ Virginis = Σ 1670

give the absolute dimensions of the orbit, nor the combined mass of the components; but since the proper motion is considerable, there is reason to believe that the parallax is sensible, and, owing to the great interest attaching to the system, it ought to be determined. The orbital motion will be slow for a number of years, but the star will deserve occasional observation so that after apastron passage (about 1932) the elements may be made definitive.

THE UNIVERSITY OF CHICAGO,
1893, Oct. 24th.

THE SYSTEM OF ζ CANCRI.

S. W. BURNHAM.

Professor Seeliger has reviewed at considerable length (A. N. 3165) his theory of the so-called dark star in the system of ζ Cancri, and criticised my paper in *Monthly Notices* (April, 1891) where I pointed out the weakness of the evidence on which this theory was based. No new facts have been advanced, and, so far as the original question is concerned, there is nothing which calls for any reply. I have given my views fully in the paper above referred to, and I see no reason for changing or modifying them in any respect; and it would add nothing to their force or value to repeat and emphasize them here. I wish only to call attention to a few points which Professor Seeliger seems to have overlooked.

I. This is not a question to be determined by an expression of opinion, however well fortified, or by adopting one of several explanations of apparently inconsistent observations. It is a simple matter of fact, and is to be established by direct evidence as in other instances of everyday occurrence. The matter stands now precisely where it did when the original paper on this subject was printed. No fact has been established since that time which can be construed to change or affect either side of the question.

II. Professor Seeliger must have read my paper in *Monthly Notices* somewhat superficially, or he would not have taken the trouble to argue that in the numerous examples which I cited of apparently variable motion, orbits should not be computed of invisible components of these systems. Of course this is correct, but that it could be done in some of these cases, and with the same propriety as in ζ Cancri, is sufficiently obvious from an inspection of the diagram I have given of the last named star, showing the observed positions side by side with the positions deduced from the theory of a disturbing body. If this latitude is allowable, then certainly there would be no difficulty in getting orbits from the measures of some of these pairs which would be on the same footing, and in every way as probable as that of ζ Cancri. I have pointed out that in all pairs of a certain class the observations show a variable motion of the companion. For the purposes of this case it is entirely immaterial whether these apparent variations are distributed regularly or otherwise. The fact that they uniformly exist is sufficient to at least throw

great doubt on any theory of a disturbing body based upon them in an isolated example. The only logical and consistent conclusion would be that these examples of variable motion furnish additional proof of the probable soundness of the theory of dark stars. This claim is not made, and evidently for the reason that these and other instances which might be cited seem to prove too much.

III. It is evident that Professor Seeliger has had little practical experience in double star work, or he would not have criticised my remark that the close pair of ε Hydræ could not possibly affect the measures of C. The truth of this statement must be so obvious to every practical astronomer who is accustomed to use the micrometer that it can hardly be considered a debateable question.

IV. I have made no objection to any general theory of dark, and therefore invisible stars. For anything we know such bodies may exist anywhere in the stellar universe. I have only undertaken to show the insufficiency of the evidence at this time to establish the existence of any such body in the system ζ Cancri; and that a more natural and probable explanation can be offered for the apparent inconsistencies of the observations. Such dark stars may exist, and if so the fact can and will be established by incontrovertible evidence; but at present, from the unsatisfactory character of the proof, it cannot be regarded as anything more in this instance than a speculation.

V. After what I have done in the last twenty years in the way of the discovery of new members to previously known systems, I trust it is hardly necessary to say that personally I should be very glad to furnish evidence from actual measures which would establish beyond all question the existence of this fourth star; and to this end I have done what should have been done many years ago as the very first step in the investigation of this matter. In my first paper on this subject, I called attention to a method by which this supposed variable motion of *C* could be established, if it really existed; and in 1891 I commenced a series of measures in the way of comparing *C* with an outside star, thus eliminating all the sources of error which might affect the position of that star when measured from the close pair. I continued these measures for two years, and then, in consequence of leaving the Lick Observatory, was necessarily compelled to give up this and all other work with the micrometer. I therefore printed these observations (*Monthly Notices*, November, 1892), and expressed the hope that others would continue the work. Whether

or not this has been done I am unable to say. I had taken it for granted that Professor Seeliger, if he had not already commenced the series of measures referred to, would at least continue the observations which in the course of a few years would settle the disputed question. Until this is done by some one, or some other reliable data is furnished, nothing is gained by re-opening, or further discussing the matter.

VI. Professor Seeliger's objection to this plan on the ground of its present incompleteness as compared with the old observations of C is valid, but it could hardly be insisted on by the advocates of this theory, since if the theory is sound it must be not only confirmed but established by this entirely independent evidence. At all events the objection would disappear by the continuance of the measures; and I had sufficient interest in ascertaining the truth, whatever it might be, to give the necessary time to the work while it was in my power to do so. The whole time necessary to make all these measures, even with an instrument as large and unwieldy as the 36-inch at Mt. Hamilton, would be less than two hours each year. The practical observer who is unwilling to spend this amount of time annually must be either remarkably busy, or have very little confidence and interest in the theory to betested. I sincerely hope that some experienced observer sometime will continue these measures for the few years necessary to settle this question. If there is any better or other way of making measures which shall help to decide the matter of variable motion, by all means let such observations be made. My only desire is to ascertain what the truth is.

CHICAGO, Sept. 1.

A NEW DISCUSSION OF PETERS' SERIES OF OBSERVATIONS TREATED BY PROFESSOR CHANDLER.*

F. FOLIE, DIRECTOR OF THE BELGIUM OBSERVATORY.

§ 1.

I was induced in 1890 to conclude from the interior fluidity of the terrestrial globe that the theoretical period of 305 days, calculated for a solid earth, could not be verified by observation; and taking half the difference of the R. A. or of the declination of the same star observed at the superior and inferior transits, or half

* Intended for the Congress of ASTRONOMY AND ASTRO-PHYSICS, but received too late for presentation.

the sum of the latitudes obtained by both transits, I thought to have determined exactly a period of 337 days for the revolutiou of the astronomical pole round the geographical.*

Other works concerning that period, and those of Chandler particularly, have encouraged me to resume that subject.

In order to take advantage of the papers of this astronomer relative to the observations of Peters at Pulkova, I intended:

1st. To examine if the only application of the Eulerian nutation does not diminish the residuals of Peters' observations more than the formula of Chandler.

2d. To deduce from the same observations, by half the difference of the latitudes obtained by two superior and inferior consecutive transits.

(*a*) The coefficient of the diurnal nutation.

(*b*) The systematic velocity.

(*c*) The correction of the constant of the annual aberration.

I had beforehand determined, by means of the observations of Gyldén:

(*a*) The constants of the diurnal nutation.

(*b*) The systematical velocity.

(*c*) The correction of theconstant of the aberration.

(*d*) The parallax of Polaris.

I shall make use of several results of this calculation in the reduction of Peters' observations, to which I shall apply the second procedure in order to diminish the number of the unknown, that without it, would be too considerable.

Let : Φ the height of the *geographical* pole, φ_s or φ_i the *astronomical* latitude determined by a superior or inferior transit by means of the usual formulæ of reduction.

z the correction of the mean adopted declination.

$\Delta\varphi$ the correction of the mean adopted latitude.

A the sum of the corrections that I adduce to the formulæ of reduction to the apparent declination not including the Eulerian nutation.

i the last correction for the superior transit.

$-i$ for the inferior.

We will have

$$\Phi = \varphi_s + z + A + i$$
$$\Phi = \varphi_i - z - A + i.$$

The half sum will give, calling φ_m that of the astronomical latitudes determined by both transits:

$$\Phi = \varphi_m + i.$$

* Annuaire de l'Observatoire royal de Bruxelles pour 1891, pp. 266-274.

Let Φ_0 be the mean adopted latitude and

$$\varphi_m - \Phi_0 = n_1;$$

we shall have

$$\varDelta\varphi = n_1 + i,$$

or, substituting for i, $u \sin \iota t + v \cos \iota t$, and for $\varDelta\varphi$, ρ, we have

$$u \sin \iota t + v \cos \iota t + \rho + n_1 = 0$$

In the half sum of the astronomical latitude determined by two consecutive transits, the one superior, the other inferior, all the errors of reduction then disappear, with exception of the Eulerian nutation.*

In the half difference, this last disappears, but all the other remain.

For the half difference gives

$$0 = \frac{\varphi_s - \varphi_i}{2} + z + A.$$

and, if

$$n_2 = \frac{\varphi_s - \varphi_i}{2}$$

$$0 = n_2 + z + A.$$

The whole of the corrections A comprise:

1st. The terms of the second order of the annual aberration and of the nutation, of which no account has been taken in the reductions; these terms may be put in the form

$$A_1 = -\tfrac{1}{4} \sin 2\delta (\varDelta\alpha)^2, \dagger$$

$\varDelta\alpha$ being the reduction to the apparent place in R. A.

I have added them to the residual n_2, which thus becomes

$$n'_2 = n_2 + A.$$

2d. The terms of the parallax, that I have made equal to $0''.05$, the value which I have deduced from Gyldén's observations, and which Chandler also found from those of Peters.

The new residuals thus become $n''_2 = n'_2 + A_2$, and we shall have, putting $A = A_1 + A_2 + A_3$:

$$0 = n_2'' + W + A_3.$$

3d. The terms of second order resulting from the combination of annual systematical aberration, these terms may be written under the form:‡

* *Loc. cit.*

† *Monthly Notices*, Vol. LII, p. 555.

* On the Formulæ of Reduction to Apparent Places of Close Polar Stars, *Monthly Notices*, Vol. LII, No. 8, p. 555. By a mistake easy to discover, this formula is written in M.N.: $KK' tg\delta(\cos \varepsilon \sin A' \cos \odot - \cos A' \sin \odot)$.

$$- KK' \, tg \, \delta \sin(A' - \alpha)(\cos \varepsilon \cos \alpha \cos \odot + \sin \alpha \sin \odot)$$

K being the constant of the annual aberration, K' the *reduced* constant, that is *projected on the equator*, of the systematical aberration.

You will remark that the factor depending on $\odot$ differs very little from that of the parallax.

This last being calculated by Nyrén, I have made use of it in order to economize time.

I have taken $A' - \alpha = 260°$, that about corresponds to the value $A' = 277°$ which I have deduced from Gyldén's observations, and to that which the modern astronomers have determined.

Putting $KK' tg\delta = y$,

$$\text{and} - \sin (A' - \alpha)(\cos \varepsilon \cos \alpha \cos \odot + \sin \alpha \sin \odot) = b'$$

we will then have to introduce in the preceding equation, amongst the terms of which A_3 is composed, the term $b'y$;

4th. The term ax which results from the correction x of the constant of aberration;

a is also borrowed from the memoir of Nyrén.

5th. The terms of diurnal nutation.

I have put the last, in declination, under the form

$$\nu[- \sin (2L + \alpha) \, \Sigma_1 + \cos (2L + \alpha) \, \Sigma_2],$$

ν representing the coefficient of the diurnal nutation, L the longitude of the first meridian (which passes through the axis of least moment of inertia A of the terrestrial crust),

Σ_1 and Σ_2 the following functions, expressed in true longitudes of the Sun and of the Moon:*

$$\Sigma_1 = - 1.155 - 0.134 \cos \Omega + 0.36 \cos 2\odot$$
$$+ 0.82 \cos 2☽ + 0.14 \cos(2☽ - \Omega) + 0.13 \cos(☽ - \Gamma')$$

$$\Sigma_2 = - 0.18 \sin \Omega + 0.39 \sin 2\odot$$
$$+ 0.89 \sin 2☽ + 0.18 \sin(2☽ - \Omega).$$

In the calculation of Peters' observations, which Chandler has combined by groups of several, I have been obliged to make abstraction of the lunar terms which must be calculated for each observation separately; I have taken account of them in those of Gyldén.

In order to avoid a too great number of unknown quantities, I have taken, in the calculation of Peters' observations, $L = 10^h$; whence

* In my *Vraite des Reductions Stellaires*, the expressions of Σ_1 et Σ_2 are given in mean longitudes.

$$\sin(2L + \alpha) = -0.69, \quad \cos(2L + \alpha) = 0.71.$$

The coefficient ν of the diurnal nutation will then be multiplied by $C = 0.69\,\Sigma_1 + 0.71\,\Sigma_2$.

Substituting for A_3 the expressions 3d, 4th and 5th given above we shall have the equation of condition

$$ax + b'y + c\nu + z + n_2'' = 0.$$

§ 2.

In the application of the equations (I) and (II) to Peters' observations, I have thought proper to suppress those of 18th December, 1842, and of 2d December, 1843, which give residuals *n*, truly excessive and still in increased by employing either the formula of Chandler or the equation (I).

To verify the period of this astronomer, I have made two hypotheses on the value of *i*, which I have supposed equal to 0°.9 and to 0°.85 by day, corresponding to periods of 398 days and of 423.5 days.*

* I have tried the period of 398 days because it agrees perfectly with the values of the angle β, deduced from $u = -\gamma \sin\beta$; $v = \gamma\cos\beta$, which have been determined by me, for 1824.0, from F. W. Struve's RA of Polaris, by Peters for 1842.0, and by Downing for 1872.0 from their observations of latitude.

It may be asked why I have adopted a period of 423.5 days instead of that of Chandler exactly; it is simply for the purpose of having a round number 0.°85 for the facility of calculation. Being obliged to make all these by myself, for want of calculators, I could not neglect any means of abridging a little of the work, already very laborious. And it is for this reason also I have borrowed from the Memoir of Nyrén the co-efficient of the parallax, although it may not be quite equal to that of my term of the systematical aberration.

It would be interesting to begin again these calculations without supposing the longitude of the first meridian to be known; then you should make

$$\nu\sin(2L + \alpha) = \xi$$
$$\nu\cos(2L + \alpha) = \eta$$

It would be very interesting to calculate, by using all the individual observations of Peters', both constants of diurnal nutation, and those of annual and systematic aberration, taking 0″.05 for the parallax.

Truly, you would have 7 unknowns; but the number of observations is great enough to permit of their determination.

By putting $\xi = \nu\sin(2L + \alpha)$, $\eta = \nu\cos(2L + \alpha)$ and calling *u* the Peters' residuals, the equation of condition will be

$$0 = u\sin it + v\cos it + ax + b'y - \Sigma_1\xi + \Sigma_2\eta + z + (n + b\omega - \tfrac{1}{4}\sin 2\delta\Delta\alpha^2),$$

where $\omega = 0''.05$, and $\Delta\alpha =$ the reduction to the apparent place in RA.

You will assume with Chandler, $i = 0°.843$ per day.

This labor is certainly worthy of trial by an astronomer who has liesure to do it, or assistants to aid him.

I regret that I am not in a position to undertake it myself.

One could reduce it considerably, and obtain nevertheless true results, I think, by adopting for *u* and *v* the values I have deduced from Chandler's table of Peters' mean latitudes, which are independent of all errors of reduction, *i. e.*,

$$u = 0''.057, \qquad v = 0''.045.$$

No doubt this computation of the complete series of Peters' observations would give much better results than I have fonnd by only 42 equations, and particularly, I think, a greater value for the constants of systematic aberration and of diurnal nutation, and perhaps, consequently, a negative correction of Struve's constant of aberration.

The application of the equation (I) to the 42 residuals given by Chandler (after the suppression of the two excessive residuals above mentioned) has given, in both hypotheses made upon the period, the new residuals n_1' and n_1''.

The sum Σwn^2 is, if we adopt the residuals of

Peters	2.68
Those of Chandler	1.88
Mine (398 days)	1.58
Mine (423.5 days)	1.43

The only application of the initial or Eulerian nutation gives then a very superior result, especially in the second case, to that of Chandler's formula, which includes an enormous annual term, absolutely empirical, and for me quite inexplicable in theory, unless it be an effect of temperature.

Independently of the terms of the aberration and of the parallax there also exists a small term which the astronomers have neglected in their formulæ and which approaches, in form, that of Chandler; it is the periodical term of systematical aberration; but all these terms are eliminated in the means of the latitudes determined by two (superior and inferior) consecutive transits; at the present I consider the initial nutation only as rendering an accurate account of the residuals thus obtained, and the result is much better than that of Chandler's empirical formula.

Is the geographical action not fixed, by action of physical causes, in the interior of the Earth? That is a question which can be only be ulteriorly resolved by the discussion of numerous and very precise observations made in places differing in longitude by 6, 12 and 18 hours, and reduced by means of absolutely correct formulæ.

§ 3.

In the application of the equation (II), I made naturally an abstract from the two observations above indicated.

n_2 indicates the residuals of Peters, n_2' those which I have deduced from them by reducing them from the terms of the second order and of the parallax.

To these last I have applied the equation (II) which gives me, by the method of Least Squares,

(1st.) Correction of the constant of the aberrations,

$$x = +\ 0''.00095;$$

(2d.) $$y = -\ 0''.035,$$

whence we deduce by taking $K = 20''.4$, since $y = -KK'$ tang δ, for the *reduced* constant of systematical aberration, $K' = 9''$.

(3d.) Constant of the diurnal nutation $\nu = 9''.255$.

The same observations gave to Chandler a positive correction $+ 0''.065$ of the constant of aberration.

Those, much more precise of Nyren, have given him a negative one $- 0''.034$; from these last I myself have obtained $- 0''.037$. It appears to me certain then that the value $20''.40$ is much better than $20''.45$.

The constant $\nu = 0''.255$ that I have deduced from Peters' observations for the coefficient of diurnal nutation is very much too great. Therefore I have taken $\nu = 0''.05, L = 10^h, A' = 280°$, and found

$$x = +0''.048, \qquad y = -0''.025;$$

whence $$K' = 2''.8, \qquad z = 0''.15;$$

what has given the residuals u_2'''.

But Peters' observations are not sufficiently precise to permit of the determination of so small a quantity as the product KK' of both constants of annual and systematical aberration.

All the criteria which may be used are nevertheless verified:

With the *positive* admitted parallax $0''.05$, our calculations give,

A systematical *positive* velocity;

A *positive* constant for the diurnal nutation.

They have led, moreover, to an insignificant correction of the constant of aberration, whilst the very precise observations of Gyldèn have given us a negative one.

A last criterion, in short, of the certainty, I will not say of the numerical results, but of the theoretical expressions of the new terms we have introduced in the formulæ of reduction (diurnal nutation and systematical aberration), is found in the sum of the squares of the residuals multiplied by the weights.

In the observations of Peters mentioned by Chandler

$$\Sigma w n_2^2 = 2.08$$

After having reduced the residuals of Peters from the terms of the second order and of the parallax this sum becomes

$$\Sigma w n_2'^2 = 1.79$$

and for our last residuals n_2'' and n_2''', it is only $\Sigma w n_2''^2 = 1.81$, $\Sigma w n_2'''^2 = 1.30$, whilst for those of Chandler (abstracts being made of the two suppressed observations) it is $\Sigma w v_2^2 = 123$.

§ 4. CONCLUSIONS.

(1.) As to the initial or Eulerian nutation, Chandler's period seems the best; and the simple application of this nutation gives much better results than Chandler's formula of *variation of latitude.*

(2.) As to the diurnal nutation, we can admit of $\nu = 0''.05$ and $L = 10^h$ E. from Pulkova.

(3.) From the parallax of Polaris we can take with certainty $\omega = 0''.05$.

(4.) As to the systematical aberration, we can admit of $A = 280°$; but the systematical velocity wants still a new determination; it is great enough, nevertheless, that we must not neglect the periodical terms of systematical aberration in the reduction of circumpolar stars.

(5.) As to the constant of annual aberration, of which little is yet known, I think the value $20''.4$ approaches more nearly the truth than $20''.45$.

In the following table the two first columns, n_1 and v_1, give the residuals of Peters and Chandler; n_1' and n_1'' my residuals in both hypotheses (period of 398 or 423.5 days); the three columns, n_2, v_2, n_2', n_2'', Peters', Chandler's and my residuals.

t		w	n_1	v_1	n_1'	n_1''	n_2	v_2	n_2'	n_2''
1842.			"	"	"		"	"		
March	14	4	+.15	+.14	+.176	+.18	+.30	+.27	+.23	+.22
	20	5	+.05	+.06	+.080	+.08	.00	−.04	+.08	+.08
April	3	3	−.20	−.18	−.164	−.17	−.13	−.18	−.21	−.19
	10	3	−.01	.00	+.027	+.01	+.09	+.02	+.01	+.04
	16	5	+.11	+.13	+.147	+.13	+.06	−.01	−.02	+.01
	28	5	+.11	+.13	+.147	+.12	−.05	−.13	−.12	−.03
May	4	3	+.10	+.12	+.132	+.10	+.30	+.22	+.23	+.23
	14	3	+.04	+.06	+.067	+.03	+.18	+.09	+.12	+.14
	24	3	+.05	+.07	+.069	+.03	+.09	+.01	+.05	+.02
	28	3	−.07	−.05	−.054	−.09	+.12	+.04	+.08	+.03
June	6	10	−.07	−.06	−.063	−.09	+.10	+.02	+.07	−.01
	22	8	−.06	−.06	−.071	−.10	+.15	+.07	+.14	−.04
July	6	7	+.02	.00	−.011	−.03	+.06	.00	+.06	−.07
	18	7	−.07	−.09	−.117	−.13	+.06	.00	+.07	−.06
Aug.	6	11	+.05	.00	−.024	−.04	−.02	−.05	+.01	−.11
	19	10	−.01	−.06	−.101	−.10	−.04	−.05	−.03	+.08
	21	6	.00	−.06	−.094	−.10	−.07	−.07	−.06	−.10
Sept.	16	8	+.16	+.08	+.054	+.06	−.05	−.02	−.04	−.01
	24	3	+.15	+.07	+.021	+.04	+.07	+.10	+.08	+.14
Oct.	4	3	+.04	−.05	−.096	−.07	−.06	−.01	−.05	+.04
	14	10	+.15	+.06	+.009	+.04	+.04	+.10	+.04	+.14
	22	3	+.23	+.14	+.087	+.12	−.19	−.12	−.18	−.08
1843.										
Feb.	1	2	−.05	−.06	−.109	−.07	−.20	−.17	−.23	−.34
	18	5	−.04	−.04	−.075	−.04	−.01	−.01	−.06	+.14
Mar.	7	3	−.04	−.03	−.060	−.04	+.03	+.01	−.03	−.07
	18	6	+.02	+.03	+.021	+.04	−.05	−.09	−.12	+.12
	24	7	−.09	−.08	−.083	−.06	.00	−.04	−.07	+.05

	$t.$	w	n_1	v_1	n_1'	n_1''	n_2	v_2	n_2'	n_2''
	1843.		"	"	"		"	"		
Apr.	3	5	−.04	−.03	−.023	−.01	+.05	−.01	−.02	+.02
	18	8	−.02	−.02	+.008	+.01	+.08	+.01	+.01	+.05
	26	7	+.02	+.02	+.052	+.01	+.03	+.04	−.03	+.00
	29	2	−.09	−.10	−.056	+.06	+.23	+.15	+.17	+.20
Sept.	14	11	+.17	+.05	+.086	+.10	−.03	.00	−.03	+.02
	25	9	+.15	+.03	+.053	+.08	.00	+.04	−.01	+.06
Oct.	6	5	+.21	+.10	+.099	+.12	−.03	+.02	−.04	+.06
	25	4	+.10	+.01	−.029	+.00	−.19	−.08	−.20	−.19
Nov.	18	2	+.44	+.38	+.298	+.03	−.03	+.05	−.04	+.00
	1844.									
Mar.	22	3	+.12	+.20	+.085	+.09	+.01	−.03	−.05	−.03
Apr.	7	7	.00	+.06	−.013	+.02	+.13	+.07	−.06	−.03
	19	6	.00	+.04	+.001	.00	+.04	−.03	−.02	+.03
May	4	6	−.16	−.14	−.144	−.15	+.06	−.02	+.01	+.03
Oct.	10	2	+.01	−.17			−.07	−.01	−.09	+.02
	31	2	−.26	−.41			−.14	−.06	−.17	+.03
	[*wnn*]	[*wvv*]	2.68	1.88	1.58	1.43	2.08	1.23	1.79	1.81

ON A NEW PENDULUM ESCAPEMENT *

The uniformity of movement of our pendulum chronometers depends mainly upon two conditions, viz., upon the accuracy of the escapement and the completeness of the compensation of the pendulum.

In both respects Mr. Sigmund Riefler, engineer and manufacturer at Munich, Germany, after many years of experimenting, has succeeded in constructing pendulum clocks which, according to the practical results recorded in the Munich Royal Observatory and elsewhere, constitute a decided progress in chronometry.

I.

The object of the escapement of this entirely new chronometric system, which also has been employed for watches and tower clocks, is to secure greater accuracy in the movement than is offered by existing escapements.

In this escapement the pendulum swings with perfect freedom, being connected with the clock-work solely through the pendulum spring from which it receives the impulse.

The impulse is communicated by the wheel-work bending the pendulum spring a little at each oscillation of the pendulum, which produces a slight tension in the spring.

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* A paper read before the Congress of Astronomy and Astro-Physics at Chicago by Mr Leman "On a New Pendulum Escapement with perfectly free pendulum, the impulse being communicated in the axis of oscillation and at the moment in which the pendulum swings through the dead point, and a New Mercurial Compensation Pendulum, invented by S. Riefler, engineer and manufacturer at Munich.

This tension-force of the pendulum spring gives the pendulum the impulse. As this bending takes place round an axis which is identical with the axis of oscillation of the pendulum, and further occurs every time almost at the moment in which the pendulum is swinging through the dead point, we gain not only the perfect freedom of the pendulum, but also the great advantage that irregularities in the communication of force from the wheel-work and in the resistances to escape can exert no detrimental influence on the uniformity of the motion of the clock. This is not only in accordance with scientific theory, but has been practically proved by the excellent performance of numerous astronomical, turret and other clocks provided with this escapement.

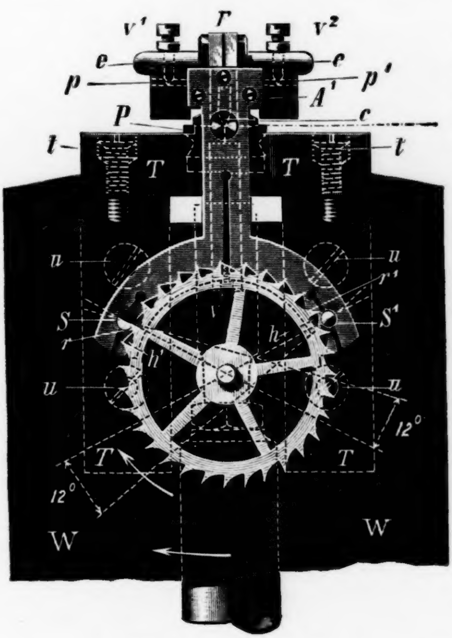


FIG. 1. Scale 5/6.

Fig. 1 of the drawings shows a front view, Fig. 2 a side view of the escapement on a scale of 5/6. Fig. 3 is the view from above in natural size dimensions for astronomical clocks.

Figs. 4 and 5 are illustrations of the suspension of the pendulum in actual size with axle and pendulum spring.

TT is a strong cast metal support fastened by four screws, *uu*, to the back plate *W* of the clock. To this support are fixed the two bearing stones *PP*, the upper surfaces of which lie in a single horizontal plane.

On this plane lies the axle of rotation *aa* of the anchor *A*, the axle being formed by the knife edges of the steel prism *cc*. The axle of the anchor receives the necessary direction for the regular locking of the anchor in the escape wheels *H* and *R* from the conical ends of the screws *KK'*, which, however, are screwed back a little when the pendulum *B* is suspended, in order not to interfere with the free play of the anchor.

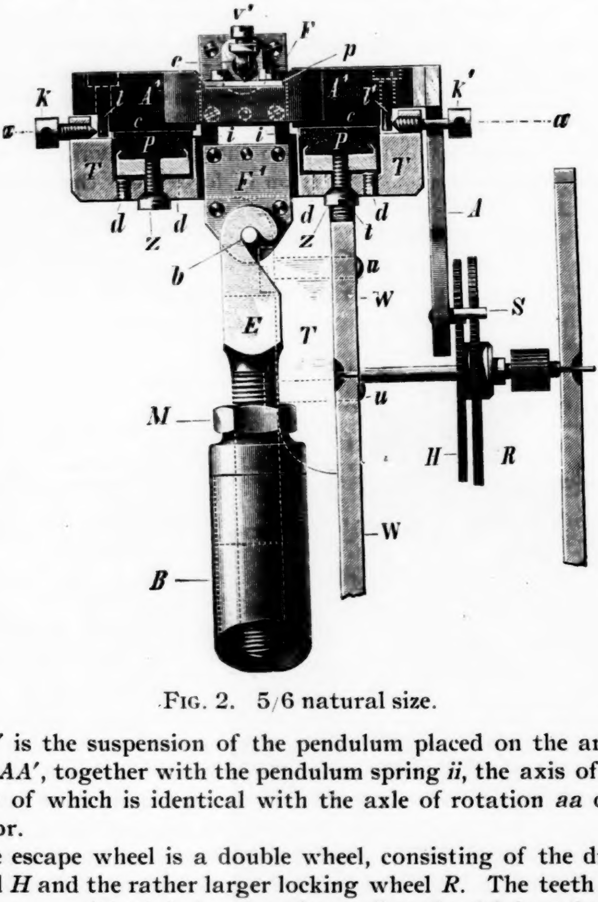


FIG. 2. 5/6 natural size.

FF' is the suspension of the pendulum placed on the anchor-piece *AA'*, together with the pendulum spring *ii*, the axis of curvature of which is identical with the axle of rotation *aa* of the anchor.

The escape wheel is a double wheel, consisting of the driving wheel *H* and the rather larger locking wheel *R*. The teeth *hh'* of the former with their bevel surfaces effect the driving, the teeth *rr'* of the latter with their radial surfaces effect the locking.

S and *S'* are the driving and at the same time the locking pallets of the anchor. They are cylindrical, and are beveled at their front ends to the centre of the axis of the cylinder.

On the cylinder surface the driving of the anchor is effected by the teeth of the driving wheel *H*, the locking is effected on the plane surfaces by the teeth of the locking wheel *R*.

The play of the escapement is as follows:

Fig. 1 shows the escapement at the moment when the pendulum is at the dead point and the teeth *r* of the locking wheel rests on the plane surface of the pallet *S*.

Now, when the pendulum swings out to the left in the direction of the arrow, the pendulum spring *ii* at first remains quite straight and the beginning of the oscillation takes place round the knife edge axle *aa* of the anchor. The anchor *A* being connected with the pendulum by the pendulum spring *ii*, will share this oscillation of the pendulum until the point of the teeth *r* of the locking wheel falls from the locking surface of the pallet *S*. Up to this point the pendulum has described an arc of about ¼°. By this time the cylindrical surface of the pallet *S'* has approached the driving tooth *h* of the driving wheel as far as is necessary for play, the wheels revolve in the direction of the arrows until the locking tooth *r'* lies on the plane surface of the pallet *S'*, and during this revolution the driving tooth *h* effects the driving: *i. e.*, it forces the pallet *S'* back and thus moves the anchor in an opposite direction to that in which the pendulum oscillates.

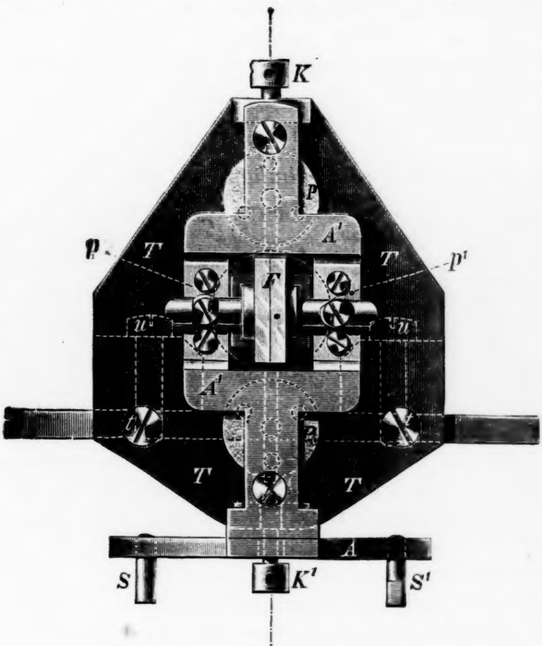


FIG. 3. Natural size.

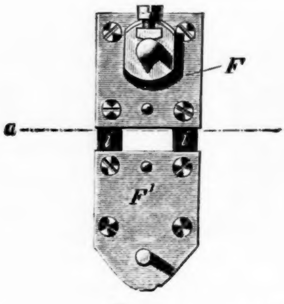
By means of this revolving motion of the anchor effected by the wheel-work the pendulum spring *ii* is slightly bent round the axis of oscillation *aa* and thus receives a slight tension which imparts the impulse to the pendulum. The pendulum, however, does not immediately yield to the impelling force, but first completes its oscillation to the left, the anchor remaining the while at rest. This complementary arc amounts to 1¼° in the astronomical clocks, and to 2½° in large turret clocks.

As the pendulum returns and after it has passed the dead-point towards the right, the tooth r' which had been resting upon S' becomes free and a new impulse takes place on the other side by means of the tooth h'.

The illustrations also show several small parts of the construction which have hitherto not been mentioned. Strictly speaking they have nothing to do with the working of the escapement, but are simply regulative appliances for its correct and convenient attachment.

The conical screw v (Fig. 1) serves to regulate the breadth of the anchor, while the depth to which the anchor locks into the escape wheels is regulated by the screws tt.

Suspension of Pendulum.



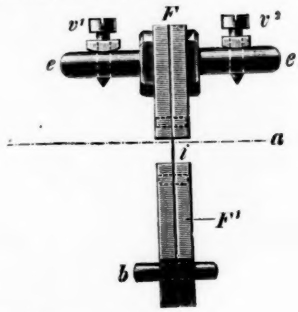


FIG. 4. Natural Size. FIG. 5.

The screws $v^1 v^2$ of the pendulum suspension, which may be kept in position by small nuts, regulate the height of suspension of the pendulum in such a way that the axis of curvature of the pendulum spring ii always coincides with the knife-edge axle, being the axis of rotation aa of the anchor. At the same time this screw regulates the regular fall of the pendulum.

The conical surfaces of the bearing screws $v^1 v^2$ of the pendulum suspension do not rest directly on the anchor-piece $A'A'$, but on thin washer-plates pp', provided with corresponding hollows and screwed onto the anchor-piece $A'A'$, but still allowing a little play in the screw-holes. In this way the knife-edge axle aa may be made to coincide accurately in a horizontal direction with the axis of curvature of the pendulum spring.

I and I' are screwed-in steel pins with conical hollows at the sides, which fit the conical points of the directive screws KK'.

The bearing stones PP rest each with its brass frame on three

pressure screws, the thread of which is in the pendulum support *T*. By means of these screws the stones are brought to the required height, and also so adjusted that their plane surfaces form a common plane. The set screws *Z* keep them in the required position.

It will be easily perceived that the resistances which operate on the pendulum in consequence of its connection with the clock-work consist solely in the friction of the axle of the anchor and in the resistance of discharge which arises when the teeth of the locking wheel glide down from the locking surface of the pallets.

Both these resistances are extremely trifling, and, in addition to this, of very constant magnitude.

The friction of the axle of the anchor consists simply of the imperceptibly small rolling friction of the steel knife-edges *cc* on the perfectly plane and very hard bearing stones *PP*. Moreover this friction influences the pendulum only for a brief moment when the pendulum is swinging through the dead point, that is to say in that portion of the oscillation, amounting to only ½°, in which the pendulum moves with the greatest speed. During much the greater part of the arc of oscillation the pendulum swings round the axis of the pendulum spring.

The resistance of discharge on the stone pallets *S* and *S'* is also almost zero, because the locking planes are not placed radially but form an angle of about 10°-12° with the radius of the escape wheels, which is equivalent to the angle of friction between stone and brass. The pallets are adjusted to slide, and not to draw as is the case with the anchors of watches.

The danger of a premature discharge is excluded, because the pallets are pressed onto the teeth of the driving wheel by the tension which the pendulum spring undergoes when the pendulum swings out.

The principal advantages of this new escapement (Germ. Imp. Pat. No. 50739) are as follows:

1. The pendulum swings with perfect freedom and without being influenced by the clock-work.

2. The impulse is communicated to the pendulum in the axis of oscillation; and the impelling lever has consequently the least possible length. The length is merely a fraction of a millimetre, since the curvature of the pendulum spring only extends over such a small space.

3. Irregularities in the transmission of force and in the resistances of discharge exert no disturbing influence on the regularity of the motion of the clock.

4. The supplementary arc of the the escapement is in astronomical clocks 3 to 5 times, and in church clocks 8 to 10 times, as great as the arc of discharge.

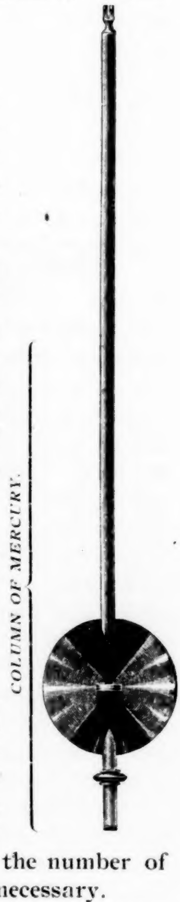
The pendulum is therefore to a high degree non-sensitive to disturbing influences of a mechanical character.

5. The number of working parts in this escapement is smaller than in any other known escapement. It consequently works with the greatest exactness.

II.

Of the different compensation-pendulums hitherto employed the mercurial compensation-pendulum invented in 1721 by the Englishman Graham enjoys the best reputation, for which reason it has beeen used in nearly all astronomical and other pendulum clocks of precision.

But even this pendulum has great defects, which are: (1) incorrect functioning when the temperature of the air differs at different levels, and (2) sensitiveness to sudden changes of temperature. Besides, the shape of this pendulum prevents it from cutting the air easily, and consequently changes in the atmospheric pressure (height of barometer) exercise a comparatively strong influence on the running of a clock having such a pendulum.



These defects are almost entirely obviated by the mecurial compensation-pendulum of Riefler (Germ. Imp. Pat. No. 60059) shown in the cut, which illustrates a second's pendulum one-tenth of the actual size.

It consists of a Mannesmann steel tube (rod), bore 16 mm., thickness of metal 1 mm. filled with mercury to about two-thirds of its length. The pndulum has, further, a metal bob weighing several kilograms and shaped to cut the air; below the bob are diec-shaped weights attached by screw-threads for correcting the compensation, the number of which may be increased or diminished as appears necessary.

Whereas in the Graham pendulum correction is effected by altering the height of the column of mercury, in this pendulum it is effected by changing the weight of the pendulum and thus the height of the column of mercury always remains the same.

A correction of the compensation should be effected, however, only in case the pendulum is to show sidereal time, instead of mean solar time, for which latter it is calculated. In this case a weight of 110 to 120 grams should be screwed on to correct the compensation.

In order to calculate the effect of the compensation it is necessary to know precisely the co-efficients of the expansion by heat of the steel rod, the mercury, and the material of which the bob is made.

The last two of these co-efficients of expansion are of subordinate importance, the two adjusting screws for shifting the bob up and down being fixed in the middle of the latter. A slight deviation is therefore of no consequence. In the calculation for all these pendulums the co-efficient for the bob is therefore fixed at 0.000018 and for the mercury at 0.00018136, being the closest approximation hitherto found for chemically pure mercury such as that used in these pendulums.

The co-efficient of expansion of the steel rod is, however, of greater importance. It is therefore ascertained for every pendulum constructed in Mr. Riefler's factory by the *physikalisch-technische Reichsanstalt* at Charlottenburg, under the surveillance of the author of this paper, his examinations showing, in the case of a large number of similar steel rods, that the co-efficient of expansion lies between 0.00001034 and 0.00001162.

The precision with which the measurements are carried out is so great that the error in compensation resulting from a possible deviation from the true value of the co-efficient of expansion as ascertained by the Reichsanstalt, does not amount to over ± 0.0017; and, as the precision with which the compensation for each pendulum may be calculated absolutely precludes any error of consequence, Mr. Riefler is in a position to guarantee *that the probable error of compensation in these pendulums will not exceed ± 0.005 second per diem and $\pm 1^\circ$ variation in temperature.*

A subsequent correction of the compensation is therefore superfluous, whereas with all other pendulums it is necessary, partly because the co-efficients of expansion of the materials used are arbitrarily assumed; and partly because none of the formulæ hitherto employed for calculating the compensation can yield an exact result, for the reason that they neglect to notice certain important influences, in particular that of the weight of the several parts of the pendulum. Such formulæ are based on the assumption that this problem can be solved by simple geometrical calcu-

tion, whereas its exact solution can be arrived at only with the aid of physics.

This is hardly the proper place for details concerning the lengthy and rather complicated calculations required by the method employed. It is intended to publish them later, either in some mathematical journal or in a separate pamphlet. Here I will only say that the object of the whole calculation is to find the allowable or requisite weight of the bob, *i. e.*, the weight proportionate to the co-efficients of expansion of the steel rod, dimensions and weight of the rod and the column of mercury being given in each separate case. To this end the relations of all the parts of the pendulum, both in regard to statics and inertia, have to be ascertained, and for various temperatures.

A considerable number of these pendulums have already been constructed, some of which have been running for more than a year. The precision of this compensation which was discovered by purely theoretical computations, has been thoroughly established by the ascertained records of their running at different temperatures.

The adjustment of the pendulums, which is, of course, almost wholly without influence on the compensation, can be effected in three different ways:

(1). The rough adjustment by screwing the bob up or down.

(2). A finer adjustment by screwing the correction discs up or down.

(3). The finest adjustment, by putting on additional weights.

These weights are to be placed on a cup attached to a special part of the rod of the pendulum. Their shape and size is such that they can be readily put on or taken off while the pendulum is swinging. Their weight bears a fixed proportion to the static momentum of the pendulum, so that each additional weight imparts to the pendulum, for twenty-four hours an acceleration expressed in even seconds and parts of seconds, and marked on each weight.

Each pendulum is accompanied with additional weights of German silver for a daily acceleration of 1 sec. each, and ditto of aluminum for an acceleration of 0.5 and 0.1 second respectively.

A metal clasp attached on the rear side of the clock-case, may be pushed up to hold the pendulum in such a way that it can receive no twisting motion during adjustment.

Further, a pointer is attached to the lower end of the pendulum, for reading off the arc of oscillation.

The essential advantages of this pendulum over the former mercurial compensation-pendulums are the following:

(1). It follows the changes of temperature more rapidly, because a small amount of mercury is divided over a greater length of pendulum, whereas in the older ones the entire (and decidedly larger) mass of mercury is situated in a vessel at the lower end of the pendulum-rod.

(2). For this reason differences in the temperature of the air at different levels have no such disturbing influence on this pendulum as on the others.

(3). This pendulum is not so strongly influenced as the others by changes in the atmospheric pressure, because the principal mass of the pendulum has the shape of a lens, and therefore cuts the air easily.

(4). *These pendulums are delivered with the compensation fully adjusted, thus avoiding all correction of the compensation,* such as is necessary with all other compensation pendulums, and which can be arrived at only after tedious experiments.

Results of Practical Tests of the Pendulum.

It was mentioned in the description of this pendulum that the accurate working of this compensation, deduced from theoretical principles, had been confirmed by the practical results. The proof of this may be found in the following extract from the table of rates registered by the Royal Observatory at Munich.

The table refers to the first pendulum of this kind, marked No. 1, which on its completion at the end of July, 1891, was to be submitted to this test, and for this purpose was hung in one of the astronomical clocks belonging to the Observatory at Munich.

This clock possesses a perfectly free escapement, German patent No. 50,739, as described above and also in numerous German and foreign technical journals as well as in Meyer's Konversations-Lexicon, Annual supplement 1890-1891, pp. 945-947. For nine months previously the clock had gone with a mercurial compensating pendulum of the hitherto usual construction; but it was not until the new pendulum was inserted that its rate attained that high degree of uniformity which corresponds to the perfection of the escapement used.

The clock stands in a room which is immediately connected with the great meridian hall of the Observatory. It is therefore subject to sudden variations of temperature of considerable degree, as the cold night air penetrates into the clock-room every

time an observation is made, and the temperature consequently sinks rapidly. The observations for time were made on every clear day by Mr. List, an assistant in the Observatory, with Reichenbach's meridian instrument. They include, as a rule, the meridian transits of several stars as well as of one or more polar stars. The days in question are given in the first column of the table. The daily rates (col. 2) indicate a certain dependence on atmospheric pressure (col. 5). The clock generally goes a little slower when the barometer is high than when it is low. The last column, therefore, contains the rates reduced to a uniform atmospheric pressure so that they may be compared directly with each other.

To reduce the mean daily rate of each series of observations (col. 3) to the mean barometric pressure of Munich 715.83 mm. (last col.), the influence of the barometer on the pendulum has been taken as 0.01 second daily for 1 mm. of alteration in the atmospheric pressure.

To enable a judgment to be formed as to the compensation for heat of this pendulum, this table contains, deduced from a long period of running, the daily rates in three series of rates during extremes of temperature.

It thus appears that the rate of the clock, from September, 1891, to December, 1891, with a maximum variation of temperature of 27° C. only varied by 9 thousandths of a second; and from December, 1891, to August, 1892, with a maximum variation of temperature of 31°, only by 2 thousandths of a second.

The error of compensation for ±1° C., therefore, amounts to only 0.0005 and 0.0001 of a second respectively. A correction of the compensation has not taken place, but the proportions of the weight and dimensions of the pendulum have remained the same as were fixed by calculation. It is to be observed that the daily fluctuation of temperature, to which the pendulum is exposed, is about 3° C.

As a verification of the foregoing data and as a testimony to the results, the following certificate from the Director of the Munish Observatory, Professor Dr. Seeliger, may be quoted here:

"From the following table of rates, extracted from the records of this Observatory, it appears that with a variation of temperature up to 30° C., no influence worth mentioning on the rate of the clock can be perceived. It is therefore probable that the new pendulum answers all requirements in as high a degree as is ever likely to be attained. A similar perfection has only exceptionally

Royal Observatory, Munich,

Extract from the Registered Table of Rates of Riefler's Astronomical Clock, No. 1

With Riefler's Perfectly Free Escapement, German Patent No. 50,739, and Riefler's Mercurial Compensation Pendulum, German Patent No. 60,059.

Date of Comparison of Time.	Observed Daily Rate. Seconds.	Mean Daily Rate of the Observed Series. Seconds.	Tempera-ture. C. deg.	Mean of Barometer. Between Two Observ-ations. mm.	Mean of Barometer. Of the Entire Series. mm.	Rate Reduced to 715.83 mm. barometer seconds.
1891 Sept. 1.....			+ 19.4			
	− 0.06			715.5		
" 2.....			+ 20.6			
	− 0.07			717.5		
" 3.....			+ 21.3			
	+ 0.06			717.8		
" 7.....			+ 18.6			
	+ 0.08	+ 0.030		719.75	719.03	− 0.002
" 9.....			+ 18.6			
	+ 0.02			722.8		
" 10.....			+ 18.1			
	+ 0.09			722.1		
" 11.....			+ 18.6			
	− 0.05			720.7		
" 12.....			+ 18.6			
1891 Dec. 5.....			+ 5.6			
	+ 0.04			718.52		
" 10.....			+ 5 0			
	+ 0.02			712.50		
" 12.....			+ 5.0			
	+ 0.11			719.16		
" 21.....			− 1.9			
	+ 0.06	+ 0.023		721.94	717.45	+ 0.007
" 23.....			− 3.8			
	+ 0.07		− 5.7	729.15		
" 28.....			− 1.0			
	− 0.02			715.80		
" 31.....			+ 4.0			
	− 0.08			710.12		
1892 Jan. 10.....			± 0.0			
1892 Aug. 16.....			+ 22.3			
	+ 0.02			720.6		
" 18.....			+ 23.8			
	− 0.01			715.3		
" 19.....			+ 25.3			
	0. 0 5			711.9		
" 20.....			+ 24.4			
	+ 0.05	+ 0.010		718.05	716.33	+ 0.005
" 22.....			+ 24.4			
	+ 0.03			715.02		
" 27.....			+ 21.3			
	− 0.01			715.52		
Sept. 1.....			+ 20.6			
	+ 0.06			720.40		
" 2.....			+ 20.6			

been attained by the ordinary compensations and even then only after long series of experiments and, strictly speaking, only by accident, while the distinguished success of this pendulum is based on calculations which may be made in advance with almost absolute accuracy. I therefore feel convinced that this new pendulum of Mr. Riefler's is a most important and welcome progress.

[Signed] H. SEELIGER,
Director of the Royal Observatory.
Royal Observatory, Munich, 3 Nov., 1892."

COMPARISON OF THE CONSTANTS OF COMPENSATION OF SOME OF THE BEST ASTRONOMICAL CLOCKS.

This table includes all clocks the rates of which have been published and were accessible to Mr. Riefler.

The last column contains references to the authorities from which the figures are taken.

No.	Name of clock and its location.	Daily variation of rate for + 1° C. sec.	Greatest difference of temp. C°	Authorities.
1	Hohwü Nr. 17	— 0.0151	17.6	Kaiser, Astr. N, vol. 63, Nr. 1502.
2	Tiede Nr. 400 Observatory Berlin	+ 0.0222	15.4	Zwink, Inaug. Dissert. 1888.
3	Knoblich Nr. 1952 Observatory Potsdam	— 0.0360	16.8	Becker, Astr. N. Vol. 96, Nr. 2290.
4	Dent, Obs'y Hongkong.	+ 0.0350	......	Doberck, Astr. N. Vol. 120, Nr. 2868.
5	Hohwü Nr. 34 Observatory Upsala	{— 0.0350 — 0.0265}	15	Schultz, Astr. N. Vol. 103, Nr. 2452.
6	Knoblich Nr. 1847	— 0.0025	19	Schumacher, Astr. N. Vol. 91, Nr. 2166.
7	Dencker Nr. 12 Observatory Leipzig	—0.0160	22	R. Schumann. Ber. d. k. s. Gesellsch. d. Wiss. 1888.
8	Hipp, Observatory Neuchâtel (1885-1887).	+ 0.0610	......	Hirsch, rapport general sur l'observ. de Neuchatel.
	Ditto (1888-1890)	— 0.0049	16.5	
9	Knoblich Nr. 1770 Observ. Bethkamp	— 0.0442	19.8	Tetens. Inaug. Dissert. 1892.
10	Riefler Nr. 1. Observ. Munich	+ 0.0008	31	Anding, Observatory Munich.

The last value was determined at the Munich Observatory by Dr. Anding from four weekly rates taken from a period covering an entire year. The value lies within the amount of the mean error. The entire results of the calculation in question will be published in the *Astronomische Nachrichten*.

The difference in the two constants of compensation of the pen-

dulum of Hipp, Neuchatel, is due to the correction of computation effected on this pendulum. Its quantity of mercury was increased by 53 gr. on February 25th, 1885, and by 570 gr. on June 7th, 1888.

As shown by this comparison, Riefler's pendulum No. 1 possesses a constant of compensation which is considerably smaller than that of any of the other pendulums compared. Riefler's pendulum has therefore stood the test of compensation brilliantly. This may be taken as a proof of the great exactitude with which the co-efficients of expansion of the Mannesmann steel tubes used for this pendulum were determined by the Imperial Physio-technical Institute, and also of the accuracy of the calculation of compensation.

As far as at present ascertained, equally favorable results have been attained with the other 27 pendulums hitherto constructed by Mr. Riefler.

THE SO-CALLED LAW OF BODE AS APPLIED BY CHALLIS TO SATELLITES.

W. T. Lynn in *Observatory* for October, gives an interesting note "On the Extension of Bode's Empirical Law of Distances of the Planets from the Sun and of Satellites from their Primaries" as applied by Challis, who drew the curious inference that there can be no planet nearer the Sun than Mercury, and no satellite nearer the several primaries than the nearest of those in each system already discovered. Mr. Lynn remarks that the last part of the inference reads oddly now in view of Professor Barnard's discovery in the system of Jupiter.

The addition of Hyperion to the system of Saturn in 1848 made it necessary for Professor Challis to introduce into the formula of the so-called law an extra term.

For Uranus, Challis obtained conformity with a series of the same form as that for Jupiter* (a, $a + b$, $a + rb$, $a + r^2b$), adding two more terms of the form $a + r^5b$, $a + r^7b$. But this is by accepting the whole of the six satellites announced by Herschel, four of which have long since ceased to be regarded as real. Challis remarks that their existence had been doubted, but thinks that the conformity of their distances to this law confirms their reality, though they were probably smaller than the two which were undoubted. The so-called law, however, cannot apparently be fitted in any shape to the distances of the four satellites which are now known and probably form the whole system. These distances are approximately in the proportion 4, 5½, 9, 12, or 3, 4, 7, 9.

* Numerically for Jupiter, 7, 7 + 4, 7 + 4 × 2½, 7 + 4 × $(2½)^2$, or 7, 11, 17, 32.

Astro-Physics.

ON THE NEW STAR IN AURIGA.*

H. C. VOGEL.

The news that a new star had been discovered in the Constellation Auriga, in the last days of January, 1892, reached me on the 2d of February, and soon thereafter came the further information that the spectrum of the star contained numerous bright lines and offered much that was of the greatest interest.

As the star was of only the 5th magnitude, it was evident that the employment of the large spectrograph which I have used for motions of stars down to the third magnitude, was out of the question; it was therefore a particularly fortunate circumstance that in January, 1892, I had constructed a spectrograph with small dispersion, which could be connected with the photographic telescope.

On account of unfavorable weather, it was unfortunately not possible to observe the new star until February 14th. Investigation with a small eyepiece spectroscope, and with a larger compound spectroscope on the 11-inch refractor, showed that the spectrum of Nova Aurigæ was remarkably like that of Nova Cygni (1876) when the latter star first appeared, and a sketch which I made agreed very exactly with the first figure in the plate which accompanies my memoir on the new star in the Swan, printed in the *Monatsberichte* of the Academy for May, 1877. The continuous spectrum was very strong and it could be traced for a surprising distance toward the violet end; it was crossed by many very broad and for the most part very bright lines, among which the hydrogen lines C and F, and three lines in the green, were particularly conspicuous. A number of broad dark bands were also recognized, but it could not be determined with certainty whether they were real, or only the result of the absence of bright lines at certain places in the spectrum. Although the spectrum was of great interest on account of this abundance of bright lines, its aspect was nevertheless not an unexpected one, for most new stars which have been observed since the introduction of spectrum analysis into astronomy have given spectra with bright lines.

* Translated from the *Abhandlungen der konigl. preuss. Akademie der Wissenschaften*, Berlin, 1893. The geographical miles in the original have been reduced to English statute miles; 1 geo. mile = 4.61 statute miles.

The result obtained by photographing the spectrum was, however, quite surprising. The spectrum extended far into the violet, and showed at the same time many bright and broad lines, among which the whole range of hydrogen lines, from F to the rythmically-ordered lines in the violet, were especially noticeable; but on the more refrangible side of most of these were broad dark lines, whose distances from the bright lines increased in going toward the violet, in proportion to the increasing dispersion of the prism, and whose identity with the bright lines was thereby established. It was at once evident that the spectrum was not that of a single body, but was made up of the superposed and relatively displaced spectra of at least two bodies, which, as shown by the displacement, were moving with great relative velocity. Several of the dark lines were afterwards recognized in visual observations, closely adjacent to the sides of the corresponding bright lines.

It cannot be said, in this connection, that the discovery of the double spectrum of the Nova is alone due to the application of photography, for with the powerful instruments of the present time the spectrum of a fifth magnitude star is bright enough, even with high dispersion, to allow the detection of the dark lines near the bright ones, and it may also be assumed that, even with instruments of moderate size the general character of the Nova's spectrum would have been correctly ascertained. The superiority of the photographic method as compared with direct observation appears most clearly and undubitably in detailed observations and measurements, which in the case of a fifth magnitude star are only in a very restricted degree possible with an instrument of small dimensions, while spectrograms taken with the same instrument allow really accurate measurement, and are capable of furnishing material for important conclusions. For this reason the detailed observation of the spectrum of such an interesting object as the Nova is not limited to instruments of the greatest dimensions.

In what follows I have given in section I the spectroscopic observations which have been made here: in section II, I have given an abstract of the most important observations of others which are so far known, particularly those which relate to the spectrum of the Nova; and, finally, in section III, the conclusions which have been drawn from the observations, together with my own views in regard to the Nova.

I. Observations at Potsdam.

The Visible Spectrum.

On Feb. 14, 1892, direct observations were made with a spectroscope of medium size provided with a slit, and with an eye-piece spectroscope, in connection with the 11-inch refractor; on the succeeding days with the eye-piece spectroscope only. The impression made by the spectrum has been described in the introductory sentences. No changes could be perceived in the first days of observation.

More detailed investigations were made on the 20th of February with the larger spectroscope above mentioned, likewise in connection with the 11-inch refractor. The dispersion of the apparatus was sufficient to allow the nickel line to be seen between the D lines in the solar spectrum. The hydrogen lines C, F, and $H\gamma$ were bright in the spectrum of the Nova, and were identified with entire certainty by means of a hydrogen spectrum tube placed in front of the slit. These lines were broad in the star spectrum, and they were perceptibly brighter and more sharply defined on the side toward the violet than on that toward the red. This appearance was especially noticeable in the case of the $H\gamma$ line. The lines were three or four times broader than the lines of the comparison spectrum; relatively to the latter they were displaced strongly toward the red, in such wise that the center of each lay outside the comparison line, which coincided with upper third of the broad line in the star spectrum. On account of the comparatively high dispersion the continuous spectrum was weak, and only the broad dark F line could be recognized with certainty, adjoining the bright line on its more refrangible side and about equal to it in breadth. The dark line was therefore completely separated from the artificial hydrogen line, and strongly displaced toward the violet.

Between C and F a great number of bright lines could be recognized, but most of them were too faint for measurement. Two of the brighter lines fell very nearly at the places of the principal nebular lines, and I therefore took some pains to determine their wave-lengths as exactly as possible. Mr. Frost, now Director of the Dartmouth College Observatory, New Hampshire, who at this time was in Potsdam, assisted me in these observations. By comparison with the lines given by a hydrogen tube, the wave-length $492.5\mu\mu$ was found for the weaker of the two lines, which was broad and ill-defined on the sides, and the wave-length $501.6\mu\mu$ for the brighter line. These determinations may be con-

sidered as accurate within the limits of about $\pm 0.3\mu\mu$, and hence it appears without doubt from the observations that the brighter line cannot be identified either with the double line of the air spectrum or with the brightest line in the spectrum of the nebulæ; it is even less possible to identify the weaker line with the second line in the nebular spectrum. On the other hand, it appears from Young's catalogue of chromospheric lines that both of the lines in question coincide with lines which are bright and of frequent occurrence in the Sun's chromosphere.

Mr. Frost and I further observed a very broad and bright line in the vicinity of the well-known magnesium group *b*, but it was not possible to determine with certainty whether the lines were to be regarded as identical. The center of the star-line coincided with the sharp edge of the brightest hydro-carbon fluting, and therefore nearly with b_4, but on the assumption that the magnesium lines would be displaced toward the red as much as the hydrogen lines, it should have been less refrangible. There is no indication that the star-line was related in any way to the hydro-carbon fluting above mentioned.

A quite bright line in the spectrum of the Nova was in all probability the line λ 531.7 always present in the spectrum of the chromosphere (the corona line). Between *b* (?) and this line two faint lines could be made out,—λ 523 and λ $528\mu\mu$. The D lines could be identified in the star spectrum with entire certainty and their displacement relatively to the comparison spectrum was distinctly perceptible.

1892, March 2. With an eyepiece spectroscope the lines C, D, several bright lines in the green, F and Hγ were recognized in the spectrum of the Nova. A broad dark band, more refrangible than C, was visible; also broad dark bands between the lines near F.

1892, March 4. Further observations were made with the eyepiece spectroscope. Dr. Wilsing and Dr. Scheiner took part in the observations. Twelve bright lines were seen in the spectrum. C was surprisingly bright and stood quite isolated, as the red of the continuous spectrum faded before reaching it. An isolated line was also seen below C at a distance from it of ½(D − C), probably the chromosphere line λ $705\mu\mu$. D was quite weak.

1892, March 16. With the eyepiece spectroscope and cylindrical lens a faint continuous spectrum was seen in the yellow and green. F was the brightest line; in addition four or five bright lines in the green were seen, and a very faint line above F, in the violet (Hγ?). D and C were no longer recognizable (Scheiner).

Without the cylindrical lens the continuous spectrum was visible from blue to red, but it was very faint. C and D could be seen as small points of light. The magnitude of the star was 8.5.

1892, March 19. The continuous spectrum is very faint, and falls off very rapidly beyond F, so that it can only be traced as far as Hγ with difficulty. Hγ is still recognizable. F is very distinctly visible, and the brightest line in the spectrum. Several lines (four or five) occasionally glimpsed in the green. C was seen by Scheiner, but not by me. The star was somewhat fainter than the 9th magnitude, its color reddish.

After its second appearance the Nova was first observed on the 17th of September, 1892, by Dr. Scheiner and Dr. Wilsing. The spectrum consisted essentially of a bright line in the green, and an extremely faint continuous spectrum. In the spectroscope without a cylindrical lens the Nova appeared unchanged as a star. A more precise determination of the position of this line in the spectrum was not possible on this evening, or on the following one, when no change in the spectrum could be perceived. In the winter the weather was so unfavorable that an observation was not possible until the 12th of March, 1893. With an eyepiece spectroscope without cylindrical lens on the 9-inch guiding telescope of the photographic refractor, the star was then perfectly unchanged. With the small spectrograph mounted on the photographic refractor (13 inches aperture) I could distinctly perceive three lines whose relative distances corresponded closely with those of the brightest lines in the spectrum of the nebulæ; besides these lines a very faint continuous spectrum was visible in their neighborhood. Taking 10 for the intensity of the brightest line in the green near λ 500, that of the second line (toward the violet from the first) would be 3 or 4, and that of the third, 1.

On account of the faintness of the object, a more accurate determination of the positions of the lines was impossible with the means at our disposal, and I therefore did not attempt it.

The Photographic Spectrum.

The apparatus used for the photographic observations has a 60° prism of very nearly colorless flint glass The dispersion from D to *h* is 4°.0. With the ordinary sensitive plates of Dr. Schleussner, the photographed spectra are about 12 mm. long from λ 490 to λ 372. The great advantage of the photographic refractor on which the apparatus was mounted, in that it unites almost in a point the photographically active rays, is shown very clearly by the fact that the spectrum is linear throughout almost its entire

extent. The spectroscope, mounted on a strong circular iron plate with projecting rim, is easily mounted on the telescope in the same way as the metal camera used for direct photographs, and by means of the draw-tube, which also serves for focusing the plates, the slit can be placed very exactly in the focus of rays having a wave-length of $420\mu\mu$. The prism is set to minimum deviation for the same rays. From λ 450 to λ 390 the spectrum is then almost equally sharp.

The photographs were measured with the same microscope which I had used in measuring the photographs taken for the purpose of determining the motions of stars in the line of sight, and which I have described more completely in the Publications of the Astrophysical Observatory.* The pitch of the micrometer screw is ¼ mm.

Since even after the first few photographs it was clear that in the spectrum of the Nova we had to deal not only with the spectra of two bodies, but possibly with the superposed spectra of several, it was not to be expected that essential information in regard to the nature of the Nova,—always the aim of the whole investigation,—could be obtained everywhere throughout the spectrum, even by the most detailed measurements; for there was no possibility of a certain identification of the lines, partly in consequence of their great breadth in the spectrum of the Nova, and partly because the chromospheric lines which are, immediately concerned in the identification, occur mostly in groups, while the broad, bright lines of the star admit of resolution in only a few cases. On this account I have confined myself to a special investigation of the hydrogen lines and the K line, since there could be no doubt in regard to their identity, and since they had moreover a special interest. It is, for instance, evident, under the microscope, that these lines, where they appear as bright lines in the star spectrum, have several maxima of brightness, and that in a second spectrum fine bright lines exist, near the middle of the dark lines which adjoin the bright lines on their more refrangible sides.

The measurements which follow relate exclusively to these lines and the above-mentioned maxima of intensity. Since it was impossible to photograph the spectrum of hydrogen at the same same time and on the same plate with the star spectrum, the spectrum of α or β Aurigæ was photographed by a subsequent exposure so as to nearly touch the spectrum of the Nova on both sides. It was first ascertained experimentally, by photographing on the same plate the spectra of widely separated stars, that the

* Publ. d. Astroph. Observ. No. 25, S. 31.

stability of the apparatus was great enough to ensure accurate comparisons and reliable measurements by the application of this method. In all except the first two photographs the slit was extremely narrow, and photographs incidentally made of α Tauri or of the Moon, with unchanged slit width, show the spectral lines with extraordinary sharpness and fineness. The exposures were mostly made by Mr. Frost and Dr. Wilsing.

In the following observations the measurements are given in revolutions of the micrometer; the change of wave-length corresponding to one revolution was found by a graphical process to be as follows:

At K	1 rev. = 2.10$\mu\mu$
H	1 rev. = 2.18 "
Hδ	1 rev. = 2.55 "
Hγ	1 rev. = 3.25 "

Plate No. 1. 1892, Feb. 14, 7^h 26^m to 8^h 21^m Potsdam Mean Time.

Plate over-exposed, on account of which the ends of the spectrum, where the photographic action is comparatively weak, are very full of detail. A second spectrum on the same plate, with about 3 minutes exposure, is more suitable for measurement in the middle of the spectrum, although beyond K in the violet it is quite faint.

Region of H and K.

Microm. rev. r	Remarks.	
0.63 1.07	Broad dark line, very diffuse.	
1.88	Dark line.	
2.52 2.56	Dark line with diffuse edges.	
2.68 2.92	Fairly bright place in spectrum, perhaps a broad line.	
2.92		Very broad, dark line.
3.28	Weak, bright line in the dark line.	
3.60		

Microm. rev. r		Remarks.
3.60		Broad bright band, diffuse toward the red.
3.69 3.85	maxima.	
4.00		
4.60		Very broad dark line.
4.95	Weak bright line inside the dark band.	
5.20		
5.20		Broad bright band, diffuse toward the red.
5.30 5.52	max.	
5.75		

Region of Hδ.

Microm. rev. r	Remarks.	
0.20		Broad dark band.
0.55	Bright line within the dark band.	
0.79		
0.79		Broad bright band less sharply bounded toward the red.
0.90 1.15	maxima.	
1.36		

Region of Hγ.

Microm. rev. r	Remarks.	
0.40		Broad dark band.
0.60	Bright line within the dark band.	
0.80		
0.80		Broad bright band somewhat less sharply bounded toward red.
0.90 1.16	maxima	
1.42		

Plate No. 2. 1892, Feb. 15, 7^h 39^m to 8^h 13^m Potsdam Mean Time.

This plate is likewise so much over-exposed that precise measurements cannot be made in the region of $H\delta$ and $H\gamma$.

Region of H and K.

Microm. rev.	Remarks.
r	
0.66 – 1.00	Broad dark line, very diffuse.
1.00	Weak bright line.
1.29 – 1.76	Broad bright line.
1.93	Bright line.
2.25	Broad, bright line, stronger than the last, perhaps 2 lines.
2.5	Dark line?
2.63 – 2.85	Broad bright line.
2.92 – 3.55 (3.30 bright line)	Broad dark line.
3.55 – 4.03 (3.65 – 3.80 maxima)	Broad dark line.
4.57 – 5.08 (4.88 Bright line)	Broad dark line.
5.08 – 5.95 (5.25 – 5.55 maxima)	Broad bright line.

Plate No. 3. 1892, Feb. 15, 8^h 42^m to 8^h 52^m Potsdam Mean Time.

In this exposure the spectrum was kept linear, and the great extension of the violet end is shown.

Plate No. 4. 1892, Feb. 15, 10^h 32^m to 11^h 37^m Potsdam Mean Time.

Taken with a larger spectrograph on the 11-inch refractor, simultaneously with the hydrogen spectrum. The photograph is so far unsuccessful that the slit was not correctly placed in the focus of the $H\gamma$ rays, and in consequence of the large chromatic aberration in the violet of the visually corrected objective, the spectrum at $H\gamma$ is very broad and weak. Only this much can be determined from the photograph;—that the greatly widened $H\gamma$ line of the star spectrum is traversed on the more refrangible side by the artificial hydrogen line, and that the line is displaced $0.7\mu\mu$ to $0.8\mu\mu$ toward the red; the middle of the broad dark hydrogen line, on the other hand, is displaced $1.0\ \mu\mu$ from the artificial line toward the violet.

Plate No. 5. 1891, Feb. 17, 9^h 15^m to 9^h 35^m Potsdam Mean Time.

The spectrum of α Aurigæ is photographed on both sides of the Nova's spectrum for determining the displacement of lines.

Region of H and K.

Microm. rev. r		Remarks.
0.69 1.03 1.13	Bright line?	Broad dark line with very diffuse edges.
1.28 1.75	Bright line, more diffuse on violet side.	
1.83	Dark line; narrow.	
2.15	Broad bright line.	
2.86	Broad bright line, diffuse toward violet.	
3.01 3.30 3.56	Bright line; weak narrow.	Broad dark line.
3.56 3.71 3.90 4.10	maxima (3.71, 3.90)	Broad bright line.
4.63 4.91 5.18	Bright line; weak.	Broad dark line.
5.18 5.34 5.53 5.84	maxima (5.34, 5.53)	Broad bright band.

Region of Hδ.

Microm. rev. r		Remarks.
0.27 0.53 0.79	line barely visible.	Dark band.
0.79 0.90 1.06 1.25 1.47	maxima (0.90, 1.06, 1.25); brightest at 1.06.	Broad bright band.

Region of Hγ.

Microm. rev. r		Remarks.
0.40 0.61 0.84	Bright line, well marked.	Dark band.
0.84 0.90 1.07 1.27 1.48? 1.65	maxima (0.90, 1.07, 1.27, 1.48?), most intense at 0.90.	Broad bright band.

Plate No. 6. 1892, Feb. 20, 6^h 35^m to 7^h 5^m Potsdam Mean Time.

A remarkably fine photograph.

Region of H and K.

Microm. rev. r		Remarks.
0.62 1.00	Broad dark line.	
1.00	Bright line?	
1.48	Very broad, bright line, diffuse on both sides.	
1.98 2.23	Bright line. Bright line.	Blend together.
2.73	Very broad bright line.	
2.95 3.25 3.55	Bright line.	Broad dark line.
3.60 3.75 3.95	3 broad bright lines, blended into a broad band. The least refrangible is the most intense.	
4 57 4.90 5.14	Bright line.	Dark band.
5.14 5.25 5.55 5.76	maxima (5.25, 5.55)	Bright band.

Region of Hδ.

Microm. rev. r		Remarks.
0.20 0.55 0.78	Very strong bright line.	Dark band.
0.78 0.87 1.15 1.38	Maxima (0.87, 1.15) very sharply marked; the less refrangible is the weaker.	Bright band.

Region of Hγ.

Microm. rev. r		Remarks.
0.33 0.61 0.84	Bright line, very distinct.	Dark band.
0.84 0.97 1.24 1.65	0.97: Very broad bright max. 1.24: Broad maximum less intense and broad than the other.	Bright band.

Plate No. 7. 1892, Feb. 20, $10^h\ 35^m$ to $11^h\ 0^m$ Potsdam Mean Time.

The exposure was unfortunately interrupted by clouds, and the photograph is decidedly inferior to the last. Nevertheless, the division of the bright lines can be recognized in this plate also.

Plate No. 8. 1892, Feb. 23, $9^h\ 30^m$ to $9^h\ 55^m$ Potsdam Mean Time.

The photograph is rather weak. Only the region of Hδ and Hγ is measured.

Region of Hδ.

Microm. rev. r	Remarks.	
0.15		Dark band.
0.57	Bright line.	
0.80		
0.83	maxima in the bright Hδ line; very distinct.	
1.15		

Region of Hγ.

Microm. rev. r	Remarks.	
0.29		Dark band
0.60	Bright line; somewhat diffuse.	
0.85		
0.93	maxima in the bright Hγ line.	
1.20		

Plate No. 9. 1892, Feb. 23, $11^h\ 15^m$ to $12^h\ 0^m$ Potsdam Mean Time.

Excellent plate, with β Aurigæ as comparison spectrum. The spectrum was made broad, whereby the Hγ and Hδ lines and the detail in their vicinity are given greater distinctness. The violet is, on the contrary, weak.

Region of H and K.

Microm. rev. r	Remarks.	
1.10 :	Bright place in the very weak spectrum.	
1.80 :		
2.00	Broad bright place.	
2.25	Broad bright place; middle.	
2.57	Broad bright place.	
2.90		
2.90		Dark band.
3.29	Bright line; easily seen.	
3.55		
3.55		Bright band.
3.59	Very narrow maximum.	
3.84	Second very broad and much brighter max.	
3.98		
4.58		Dark band.
4.91	Bright line.	
5.15		
5.15		Broad bright line.
5.23	Very narrow maximum.	
5.54	Very broad maximum.	
5.80		

Region of Hδ.

Microm. rev. r	Remarks.	
0.15		Dark band.
0.57	Bright line.	
0.70		
0.70		Bright line.
0.88	maxima.	
1.15		
1.33		

Region of Hγ.

Microm. rev. r	Remarks.	
0.25		Dark line.
0.60	Bright line; weak and broad.	
0.78		
0.78		Bright line.
0.90	maximum.	
1.18	Second max. like the first.	
1.45		

Plate No. 10, 1892, Feb. 25, $6^h\ 45^m$ to $7^h\ 20^m$ Potsdam Mean Time.

Excellent photograph. Spectrum of β Aurigæ on both sides, very close to the spectrum of the Nova; consequently very exact measurments of displacement.

Region of H and K.

Microm. rev. r		Remarks.
1.18		
1.48	Brighest phase	Bright, broad line; diffuse.
1.82		
2.62	Bright line.	
2.88	Bright line.	
2.88		
3.27	Bright line very prominent	Dark line.
3.54		
3.54		
3.65	Maximum weak	
3.84	Max. impression exactly that of a double line	Bright line.
3.90		
4.02		
4.61		
4.90	Bright line	Dark iine.
5.18		
5.18		
5.22	Maximum; narrow.	
5.45	Max.; very broad and bright.	Bright line.
5.57		

Region of Hδ

Microm. rev. r		Remarks.
0.20		
0.56	Bright line	Dark line.
0.78		
0.78		
0.92	Maxima	Bright line.
1.17		
1.30		

Region of Hγ

Microm. rev. r		Remarks.
0.29		
0.60	Bright line	Dark line.
0.78		
0.78		
0.90	Maximum.	
1.12	Max.; brighter than the last.	Bright line.
1.45		

Plate No. 11, 1892, Feb. 26, 7^h Potsdam Mean Time.

Weak plate, taken through clouds; not suitable for precise measurement. β Aurigæ as comparison spectrum. It is noteworthy that H and Hγ are almost equal in intensity; Hδ, on the contrary, is considerably weaker.

Plate No. 12, 189?, March 2, 9^h 30^m to 10^h 30^m Potsdam Mean Time.

Successful photograph, highly interesting on account of the great changes which have taken place in the violet part of the spectrum, and particularly in the K line. β Aurigæ as comparison spectrum.

Region of H and K.

Microm. rev. r		Remarks.
0.58	Dark line with very diffuse borders.	
0.98		
1.26	Dark line; narrow.	
1.28		
1.55	Middle and most intense place.	Bright line.
1.86		
2.65	Rather bright place in continuous spectrum. At 3.17*r* perhaps a narrow line.	
3.30		
3.33	Dark line; very sharply marked	
3.53		

Microm. rev. r		Remarks.
3.53		
3.66	Maxima	Bright line.
3.89		
4.08		
4.53	Weak bright line; narrow.	
4 58		
4.88	Bright line, somewhat diffuse, perhaps double (4.80*r*, 4.93*r*)	Dark line.
5.18		
518		
5.25	Max., narrower and weaker than the following.	Bright line.
5.53	Maximum.	
5.74		

Region of Hδ.

Microm. rev. r		Remarks.
0.13		Bright line.
0.56	Bright line; somewhat diffuse toward the violet; perhaps 2 lines.	
0.80		
0.80		Bright line.
0.87	Maxima	
1.10		
1.38		
(1.43)	Entirely isolated line perhaps a fault in the plate.	

Region of Hγ.

Microm. rev. r		Remarks.
0.30		Dark line.
0.55	Bright lines blended together.	
0.68		
0.85		
0.85		Bright line.
0.92	Maxima	
1.15		
1.39		
1.52		

Plate No. 13, 1892, March 3, $7^h\ 0^m$ to $8^h\ 0^m$ Potsdam Mean Time.

Excellent plate, with β Aurigæ for comparison spectrum.

Region of H and K.

Microm. rev. r		Remarks.
0.60	Dark line with very diffuse borders.	
0.95		
1.25	: Dark, diffuse line.	
1.50	Brightest place in a broad, very diffuse band.	
2.39	Rather dark place in spectrum.	
2.58		
3.35	Dark line very sharply bounded.	
3.55		
3.55		Bright line quite sharply bounded on the red side.
3.63	Maxima all somewhat vague.	
3.80 ?		
3.95		
4.08		
4.50	Narrow bright line.	
4.56		Dark line.
4.78	Two delicate bright lines, blended together.	
4.94		
5.19		
5.19		Bright line.
5.28	Maximum; narrow.	
5.50	Max.; broad and strong.	
5.85		

Region of Hδ.

Microm. rev. r		Remarks.
0.15		Dark line
0.48	Weak and broad bright line with two maxima.	
0.62		
0.85		
0.85	Max. not well separated	Bright line.
0.91		
1.13		
1.39	Perhaps a line.	

Region of Hγ.

0.32		Dark line.
0.60	Broad, diffuse; not certainly double.	
0.80		
0.80		Bright line.
0.94	Max. narrower than the following.	
1.13		
1.44		
1.51		

Plate No. 14, 1892, March 4, $7^h 0^m$ to $8^h 0^m$ Potsdam Mean Time.

One of the finest plates obtained. Spectrum kept somewhat wide, and hence rather weak in the violet. Reliable measures with comparison spectrum of β Aurigæ.

Region of H and K.

Microm. rev. r	Remarks.	
1.14	Quite diffuse.	A piece of the continuous spectrum.
2.17	Diffuse.	
2.67	Broad bright line; weak.	
3.17	Perhaps two bright lines; otherwise a pretty broad band, weaker than the preceding line.	
3.55		Bright band.
3.59	Maximum.	
3.90	Max.; weaker than the preceding.	
4.04		
4.53		Dark line.
4.88	Broad bright line; quite weak.	
5.18		
5.18		Bright line.
5.26	Maximum; weak.	
5.51	Max.; very bright and broad.	
5.75		

Region of Hδ.

Microm. rev. r	Remarks.	
0.13		Dark line.
0.55	Broad bright line; distinctly marked (intense).	
0.79		
0.79		Bright line.
0.91	maxima; equally bright.	
1.13		
1.35		

Region of Hγ.

Microm. rev. r	Remarks.	
0.23		Dark line.
0-60	Bright line, not very prominent.	
0.85		
0.85		Bright line.
0.91	maxima; equally bright.	
1.20		
1.51	Fairly sharp borders.	

Plate No. 15, 1892, March 5, $7^h\ 20^m$ to $7^h\ 40^m$ Potsdam Mean Time.

Spectrum of the Nova somewhat weak. The spectrum of the Moon with full slit-width and with 10 seconds exposure was photographed on the star spectrum. The displacement of the bright hydrogen lines Hγ, Hδ and H, is shown very clearly in this way. Hγ and Hδ in the lunar spectrum coincide exactly with that maximum of the corresponding bright lines in the spectrum of the Nova which lies toward the violet side.

Plate No. 16, 1892, March 9, $7^h\ 37^m.5$ to $8^h\ 22^m.5$ Potsdam Mean Time.

As in the last plate, the lunar spectrum is photographed also, but it is so intense that the spectrum of the Nova is hardly recognizable.

Plate No. 17, 1892, March 9, $9^h\ 50^m$ to $10^h\ 10^m$ Potsdam Mean Time.

Like the last plate. The star spectrum can be seen better; but there is nothing in this plate worthy of remark.

Plate No. 18, 1892, March 13, $7^h\ 0^m$ to $8^h\ 0^m$ Potsdam Mean Time.

Spectrum kept quite linear. The continuous spectrum has almost completely disappeared, and the bright lines appear as isolated, somewhat elongated knots of light. The following lines could be measured with certainty (compare with a table given further on, of all the lines measured in the spectrum when the star was still brighter):

K	933$\mu\mu$	Hδ	410$\mu\mu$	426 $\mu\mu$	Hγ 434$\mu\mu$
H	397		418	429	452
	407		423	431	456
					458

Plate No. 19, 1892, March 16, 7^h 30^m to 9^h 0^m Potsdam Mean Time.

The plate still shows many lines like those of the last plate. β Aurigæ as comparison spectrum. The following lines were measured:

α	$389\mu\mu$		$429\mu\mu$
K	393	$H\gamma$	434
	397		442
	407		452
$H\delta$	410		456
	418		458
	421 }		
	424 }		

The positions of the hydrogen lines, from the mean of several measurements of the spectra of the comparison stars α and β Aurigæ, taking into account the motions of the Earth and Sun at the time of observation, are, $H = 5.36r$, $H\delta = 0.92r$, $H\gamma = 0.92r$. Measurements of the difference $K - H$ in the spectra of various other stars, in which the K line is visible, give $K = 3.73r$. If we now form with these values the differences of the measured lines, we obtain the displacements of the lines in the spectrum of the Nova in micrometer revolutions, or, with the aid of the table on page 902, in wave-lengths; and finally, by means of the values following, the motion corresponding to these displacements in miles:

1 $\mu\mu$ at	K	corresponds to	473 8	miles.*
"	H	"	469.6	"
"	$H\delta$	"	454.4	"
"	$H\gamma$	"	429.3	"

I shall now bring the observations together in tabular form, remarking that a negative motion signifies approach, a positive one recession, with respect to the Sun; further that plates marked (*) have a comparison spectrum photographed on them alongside of the spectrum of the Nova, and are therefore available for determining the relative motion of the Nova and Sun, while the other observations cannot be regarded as decisive in this respect.

In these plates the starting point of the measurements was so chosen that they could be connected in the most exact manner possible with those first mentioned, under the assumption of constancy in the positions of the fine bright lines which appear in the dark K, H, $H\gamma$ and $H\delta$ lines. In regard to the relative positions of the individual measured points, all the observations are of equal value.

* English statute miles.

K

No. of Plate	Displacement in Rev.			Displacement in μμ			Velocity in Miles.		
	Bright line in dark.	First Max.	Second Max	Bright line in dark.	First Max.	Second Max.	Bright line in dark.	First Max.	Second Max.
1	− 0.45	− 0.04	+ 0.12	− 0.95	− 0.08	+ 0.25	− 452	− 37	+ 120
2	− 0.43	− 0.08	+ 0.07	− 0.90	− 0.17	+ 0.15	− 424	− 78	+ 69
5*	− 0.43	− 0.02	+ 0.17	− 0.90	− 0.04	+ 0.36	− 424	− 18	+ 171
6	− 0.48	− 0.06	+ 0.22	− 1.01	− 0.12	+ 0.46	− 479	− 55	+ 217
9	− 0.44	− 0.14	+ 0.11	− 0.92	− 0.29	+ 0.23	− 438	− 138	+ 111
10*	− 0.46	− 0.08	+ 0.15	− 0.97	− 0.17	+ 0.32	− 461	− 78	+ 152
12*		− 0.07	+ 0.16		− 0.15	+ 0.34		− 69	+ 161
13*		− 0.10	+ 0.22		− 0.21	+ 0.46		− 101	+ 217
14*		− 0.14	+ 0.17		− 0.29	+ 0.36		− 138	+ 171
	− 0.45	− 0.08	+ 0.15	− 0.94	− 0.17	+ 0.33	− 447	− 78	+ 152

H

1	− 0.41	− 0.06	+ 0.16	− 0.89	− 0.13	+ 0.35	− 420	− 60	+ 166
2	− 0.48	− 0.11	+ 0.19	− 1.05	− 0.24	+ 0.41	− 493	− 111	+ 194
5*	− 0.45	− 0.02	+ 0.17	− 0.98	− 0.04	+ 0.37	− 461	− 18	+ 175
6	− 0.46	− 0.11	+ 0.19	− 1.00	− 0.24	+ 0.41	− 470	− 111	+ 194
9	− 0.45	− 0.13	+ 0.18	− 0.98	− 0.28	+ 0.39	− 461	− 134	+ 184
10*	− 0.46	− 0.14	+ 0.09	− 1.00	− 0.31	+ 0.20	− 470	− 147	+ 92
12*	− 0.48	− 0.11	+ 0.17	− 1.05	− 0.24	+ 0.37	− 493	− 110	+ 175
13*	− 0.50	− 0.08	+ 0.14	− 1.09	− 0.17	+ 0.31	− 507	− 78	+ 147
14*	− 0.48	− 0.10	+ 0.15	− 1.05	− 0.52	+ 0.33	− 493	− 101	+ 157
	− 0.46	− 0.10	+ 0.16	− 1.01	− 0.21	+ 0.35	− 475	− 97	+ 166

Hδ

1	− 0.37	− 0.02	+ 0.23	− 0.94	− 0.05	+ 0.59	− 429	− 23	+ 267
5*	− 0.39	− 0.02	+ 0.14 + 0.33	− 0.99	− 0.05	+ 0.36 + 0.84	− 447	− 23	+ 161 + 383
6	− 0.37	− 0.05	+ 0.23	− 0.94	− 0.13	+ 0.59	− 429	− 60	+ 267
8	− 0.35	− 0.09	+ 0.23	− 0.89	− 0.23	+ 0.53	− 406	− 106	+ 267
9	− 0.35	− 0.04	+ 0.23	− 0.89	− 0.10	+ 0.59	− 406	− 46	+ 267
10*	− 0.36	0.00	+ 0.25	− 0.92	0.00	+ 0.64	− 420	− 0	+ 290
12*	− 0.36	− 0.05	+ 0.18	− 0.92	− 0.13	+ 0.46	− 420	− 60	+ 207
13*	− 0.44 − 0.30	− 0.01	+ 0.21	− 1.12 − 0.77	− 0.03	+ 0.54	− 507 − 350	− 14	+ 244
14*	− 0.37	− 0.01	+ 0.21	− 0.94	− 0.03	+ 0.54	− 429	− 14	+ 244
	− 0.37	− 0.03	+ 0.22	− 0.93	− 0.08	+ 0.54	− 424	− 37	+ 258

Hγ

No. of Plate.	Displacement in Rev.			Displacement in $\mu\mu$			Velocity in Miles.		
	Bright line in dark.	First Max.	Second Max.	Bright line in dark.	First Max.	Second Max.	Bright line in dark.	First Max.	Second Max.
1	− 0.32	− 0.02	+ 0.24	− 1.04	− 0.07	+ 0.78	− 447	− 32	+ 337
5*	− 0.31	− 0.02	+ 0.15 } + 0.35 }	− 1.01	− 0.07	+ 0.48 } + 1.13 }	− 433	− 32	{ + 207 { + 484
6	− 0.31	+ 0.05	+ 0.32	− 1.01	+ 0.16	+ 1.04	− 433	+ 69	+ 447
8	− 0.32	+ 0.01	+ 0.28	− 1.04	+ 0.03	+ 0.91	− 447	+ 14	+ 392
9	− 0.32	− 0.02	+ 0.26	− 1.04	− 0.07	+ 0.85	− 447	− 32	+ 364
10*	− 0.32	− 0.02	+ 0.20	− 1.04	− 0.07	+ 0.65	− 447	− 32	+ 281
12*	− 0.37 } − 0.24 }	0.00	+ 0.23	− 1.20 } − 0.78 }	0.00	+ 0.75	− 516 } − 336 }	0	+ 323
13*	− 0.32	+ 0.02	+ 0.21	− 1.04	+ 0.07	+ 0.68	− 447	+ 32	+ 290
14*	− 0.32	− 0.01	+ 0.28	− 1.04	− 0.03	+ 0.91	− 447	− 14	+ 392
	− 0.32	0.00	+ 0.25	− 1.03	− 0.01	+ 0.82	− 442	− 5	+ 350

Considering the great difficulty of fixing the by no means sharply bounded maxima, and of measuring in such a short spectrum ($0.04r = 0.01mm$ corresponds in the average to a motion of 46 miles per second), the observations agree quite well, and prove a remarkable constancy in the relative distances of the lines which were measured.*

The following table contains the widths which I have found for the bright and the dark Hδ and Hγ lines from the mean of all the measured plates; also the displacement of the middle points of these lines with respect to the lines of the comparison spectrum (after reduction to the Sun), from the mean of plates 5, 10, 12, 13 and 14, and the velocities corresponding to these displacements in English miles.

Line.	Breadth in $\mu\mu$	Displacem't of the middle in $\mu\mu$	Velocity.
Hδ, bright	1.49	+ 0.44	+ 198
Hγ, bright	2.28	+ 0.85	+ 364
Hδ, dark	1.53	− 1.10	− 498
Hγ, dark	1.65	− 1.15	− 493

* I should not wish to leave unmentioned that, with Dr. Scheiner I made some preliminary measures of the plates last year which gave the result — 433, — 41, + 281 miles (relatively to the Sun). A. N. 3079.

In regard to the appearance of the dark lines I have still to remark that on several plates the impression which these plates gave me was this; that they were partially covered by the bright lines where they came in contact with the latter, *i. e.*, on their less refrangible sides, and that perhaps the centre was therefore indicated by the fine bright line. The idea that the fine line is to be regarded as a reversal at once suggests itself. However, other plates, particularly those which were longer exposed, show that the maximum darkening in the lines lies somewhat to the violet side of the fine bright lines. If these places are regarded as the centres of the dark lines their displacement corresponds to a velocity of 507 miles per second.*

Finally, I have collected in the following table, the wave-lengths of the brightest lines in the visible and photographic spectrum of the Nova, deduced for the most part from repeated measurements, and have added for comparison the brightest lines in the chromosphere spectrum according to Young.

Lines in Spectrum of the Nova.	Remarks.	Chromosphere Lines
$\mu\mu$		
705	Bright line	705.6
656.2	Very bright line	Hydrogen, C
568.6*	At first broad and very bright	Sodium, D
531.7	Quite bright line	Corona line (Fe)
528 : 523 :	Fairly bright lines	528.5 (Fe, Ti) 523 5 (Fe, Mn, Zn)
516.7	Bright, very broad, diffuse on both sides..	518.4 517.2 516.9 516.8 (Mg *b* ?)
501.6	Bright, broad	501.9 501.6 (Fe, Ni, Ti)
492.5 492.3	Line, somewhat more diffused on red side measured on plate 1 only	493.4 492.4 492.2 491.9 (Ba, Fe, Zn)
486.2	Broad, bright	Hydrogen, F
....	On plate 2 several lines can be recognized.	
462.8	Broad bright line, recognizable on plate 2 only	463.0 (Fe, Ti, N)
458.3	Broad, bright line	458.4 (Fe)
455.7	Broad line	456.6 456.4 456.0 455.6 455.4 455.0 (Fe, Ba, Ti)

* A lithographed plate in the original shows the appearance of the principal measured lines on the best plates.

Lines in Spectrum of the Nova.	Remarks.	Chromosphere Lines.
453.0 } 452.0 }	Broad bright line in spectrum....................	453.4 } 453.3 } 452.5 } (Fe, Ba, Ca, Ti) 452.3 }
450.7	Middle of a group of lines measured on plate 6 only..	450.2 (Ti)
449.5 } 448.0 }	Broad bright band....................................	449.2 (Mg) } 449.0 (Fe) }
447.3	Broad line, hard to fix...............................	448.1 (Mg, Fe) } 447.2 (Ce) } 447.0 (Fe, Ti) }
444.5	Middle of a group of lines.......	444.4 (Fe, Ti)
443.5	Broad bright line...........	
441.7	Broad bright line.......................................	
438.3	Bright place in spectrum...........................	439.5 } 438.5 } 437.6(Fe) } 437.5(Fe) }
434.1	Very bright line, 2 maximа........................	Hydrogen, Hγ
431.5	Broad bright line.......................................	
428.8	Broad bright line.......................................	
426.2	Bright line very broad.............................	
423.0	Broad bright line.......................................	423.6 (Fe) } 423.4 (Fe, Ca) }
417.6	Very broad bright line..............................	
415.8	Measured on plate 6 only...........................	
412.5	Measured on plate 5 only...........................	
410.2	Broad, bright, 2 maxima...........................	Hydrogen, Hδ
406.7	Broad bright place in spectrum; measured on plate 6 only, but perceptible on plates 18 and 19 also..	
396.9	Very broad; 2 maxima.......................	Hydrogen, H (Fe, Ca)
393.4	Broad, 2 to 3 maxima................................	K (Fe, Ca)
388.9	Broad and very bright...............................	Hydrogen, α
383.5	Broad bright line..	Hydrogen, β

* So printed in the original; perhaps 586.6 or 589.6.—*Tr.*

TO BE CONTINUED.

HYDROGEN ENVELOPE OF THE STAR DM. + 30° 3639.*

W. W. CAMPBELL.

The 9.3 magnitude star DM. + 30° 3639 is surrounded by an extensive hydrogen envelope. This star is of the Wolf-Rayet type, and its spectrum is very rich in bright lines, about thirty having been observed by me between wave-lengths 656 and 426. The most striking features of the visual spectrum are the continuous spectrum, the bright line at λ 5694, the bright blue band at λ 4652 and the very bright hydrogen Hβ line. When the appara-

* Communicated by the author.

tus is in focus for the different parts of the spectrum referred to, the line at λ 5694 is a very small round image of the star; the band at λ 4652 is broad and lies wholly upon the narrow continuous spectrum: but the Hβ line, observed with a narrow slit, is a long line extending a very appreciable distance on each side of the continuous spectrum; and with an open slit is a large circular disc about 5″ in diameter. The appearance of the Hβ line is best shown by the accompanying sketch.

The same appearance is noticeable in the faint Hγ and very aint Hα lines. It is not noticeable in the other lines of this spectrum, nor has it been seen seen in the spectra of any other stars of this type. It is due to an envelope of incandescent hydrogen. Whether the large disc is wholly due to an unusually extensive atmosphere, or in part to proximity to the solar system, will be tested by further observation to be made here.

The existence of this hydrogen envelope can hardly fail to have an important bearing upon the theory of bright line stars.

MT. HAMILTON, Oct. 1.

THEORY OF THE SUN.*

A. BRESTER, JR.

In a memoir published in 1892 by the Royal Academy of Sciences of Amsterdam, and entitled "Theory of the Sun," I have endeavored to show that, if the ideas already firmly established and generally received at the present time as to the gaseous nature of the Sun and the cloud-like state of the photosphere have not yet led to any plausible explanation of the incessant and more or less irregular or periodic phenomena exhibited by the Sun, the fault rests solely in the hypothesis of solar eruptions; an hypothesis which, at first suggested by the deceptive appearance of a certain variety of prominences, and strongly supported

* Read at the Congress of Astronomy and Astro-Physics, Chicago, August, 1893.

by the ordinary interpretation of the displacement of spectral lines, is in direct contradiction with many phenomena.

In rejecting this hypothesis we arrive at the conception of a relatively tranquil gaseous Sun, which is composed, according to the memorable discovery of Kirchhoff, of the same matter as our Earth. It is then possible to discover, according to the well known properties of this matter, what is the cause of its immobility, and to demonstrate that this same cause, which keeps the mass in repose, must also produce "chemical luminescence" and thereby moving flashes in the tranquil matter that have often the deceptive appearance of great material eruptions.

Such is my new chemical theory. If I introduce here some of its salient points, it is in the hope that their presentation at the Congress at Chicago will encourage some investigators to study my theory itself in the memoir to which I have referred.

Let us see in the first place what are the arguments which should lead us to acknowledge the tranquility of the Sun's interior and the character, often so deceptive, of the prominences which have been called "eruptive."

1. *The continuous stratification of the solar atmosphere*, which in that very place where the prominences traverse it without cessation, preserves indefinitely the same metallic vapors buried in its depths. This stratification of solar gas is an established fact shown by the spectroscope. If the metallic vapors, which are seen only in the depths of the chromosphere, were actually to rise into the higher regions of the solar atmosphere, it is not clear why their spectral rays should not appear there, when the rays of hydrogen, for example, are shown so plainly. We know in fact there are no vapors which exhibit their lines more easily than metallic vapors, and that those of incandescent hydrogen on the contrary are shown with difficulty. It is also doubtful whether hydrogen, even at its great temperature while burning in excess in oxygen, is sufficiently heated to produce lines. The experiments which Plücker and, quite recently, Liveing* have made to decide this question, have given contradictory results.

We have, moreover, no reason for admitting that there is a rapid diminution in temperature in the solar atmosphere, which is still incandescent in the most remote regions of the corona, and there, when by chance such comets as that of September, 1882, and that of Wells, have approached very near the Sun, we have

* Plücker, *Pogg. Ann.*, 116, p. 48. Liveing, *Phil. Mag.*, Oct. 1892. On Plücker's supposed detection of the line spectrum of Hydrogen in the oxy-hydrogen flame.

been shown as a proof of the great reinforcement of their heat, the vaporization of sodium and iron in their mass. Now if an approach to the Sun renders iron itself vaporous and spectroscopically visible in the infinitely rarified substance of a comet, it is not clear how the same metal at a shorter distance from the Sun, if really present in the upper layers of the solar atmosphere, could be incapable of there manifesting its lines.

The Sun's atmosphere then is not homogeneous* but has a real stratified structure and in its upper layers the lightest elements predominate. But a similarly stratified gaseous structure does not obtain except in an absolutely tranquil gas. Under this condition it is also foreseen in the kinetic theory of gases. It is absolutely incompatible with the hypothesis of solar convulsions. We know moreover that in our own atmosphere, movements a thousand times smaller are quite sufficient to prevent the least stratification.

2. *The tranquility already generally admitted of those prominences which are known as quiescent* and which, floating like clouds in the upper regions of the Sun's atmosphere, kindle and die out, now and then without any connection binding them to the distant chromosphere. According to Young, "the general appearance of these objects indicates that they originate where we see them and are formed by a local heating or by some luminous agitation of the hydrogen already present, and not by a transportation of matter, taken from a distance."† When the prominence disappears, says Lockyer,‡ it is not that the matter disappears; it changes its state, and this change is chiefly in temperature. Although Young and Lockyer have not mentioned the combination of dissociated elements as a cause for "the luminous agitation in the hydrogen already present," their explanation of the quiescent prominence is for the rest quite the same as that which I would also apply to all prominences without exception.

3. *The stratification of eruptive prominences* which in showing us certain metallic vapors near their bases only, also harmonize poorly, it seems to me, with the idea of homogeneous gaseous masses shooting in a few minutes from the depths of the photosphere to elevations of hundreds of millions of meters. It cannot be admitted that in such eruptions gravitation keeps these vapors from rising higher than a minute of arc, while the lighter elements alone continuing their ascent, sometimes quickly

* Ranyard: *Knowledge*, 1893, p. 30.
† Young: The Sun, p. 166.
‡ Lockyer: Chemistry of the Sun, p. 415.

attain height eight or more times greater. It does not seem, moreover, that the small height to which these heavier metals appear to rise depends always on the violence of the eruption as one would naturally suppose. The great prominence of July 1, 1887, displayed no metallic lines, while the low prominences of May 21, 1887, showed many of them.* In the prominence of June 17, 1891, Trouvelot and Fényi both observed that the number of metallic lines was not at all proportionate to the exceptional violence of the supposed eruption,† and upon the authority of Secchi, it is ordinarily the small eruptions which are remarkable for their abundance of metallic vapors.‡ Surely there is in this stratification of eruptive prominences something which makes us think rather of some "luminous agitation" of a stratified atmosphere already present than of a sudden eruption of "matter brought from a distance."

4. *The forms of the prominences* which, chiefly when they are disrupted, and present constant and irreconcilable changes of direction, are incapable of giving us the idea of an eruption or of an explosion of any kind. Especially when these prominences, separated into fantastic and dissimilar filaments, are of great dimensions (as that of Oct. 3, 1892, for example, which extended over 30° of the Sun's limb and reached an elevation greater than half the solar radius), it becomes impossible to recognize there a real material movement. Is it not surprising also that Fényi in describing a similar prominence, probably the largest ever observed, has taken opportunity to call attention to my new theory in which "neither the ragged outlines of the image nor their great extent present any difficulties."§

I am well aware that the prominences are not always of such fantastic forms and that many of them too have flame-like jets much resembling veritable eruptions. But this apparent resemblance must be accepted with much caution. The cirrous clouds of our own atmosphere also often seem to be arranged by some powerful current. But this phenomenon is surely deceptive when it is seen to be produced by the cirri forming suddenly and then spreading almost instantaneously over the greater part of the sky with their filaments straight or gracefully curved, parallel or divergent.‖ All those prominences, moreover, which show us

* Publications of the Haynald Observatory, VI Heft. 1892, pp. 13 and 23.

† Fényi, S. J., *Mem. d. Soc. d. spettrosc. Italiani*, Vol. XXI (1892) Tav. 276.

‡ Secchi, *Le Soleil*, II, p. 149.

§ Fényi, *Mem. d. Soc. d. Spettrosc. Italiani*, Vol. XXI (1892). Note sur une Protubérance excessivement grande observée le 3 Oct., 1892, à l'observ. Haynald.

‖ W. v. Bezold: *Himmel und Erde*, Oct., 1892. Secchi: *le Soleil* I, p. 119. Liais: *l'Espace celeste*, p. 49.

sheafs and particularly jets clearly defined and arranged in fans or radiating systems, have indeed the appearance of eruptions. But these appearances represent the facts of the case only when we suppose them to be produced by something analogous to sky-rockets or to divergent jets of a fountain of burning liquid. But as spectral analysis teaches us that they are produced by an incandescent gas, I cannot believe that the forms result from actual motion. Let us consider, for instance, the prominence which Secchi has reproduced in Fig. 5 of Plate E of his treatise on the Sun. We see there seven diverging rays in the shape of a fan. Secchi* says, "These rays were *perfectly straight* and very clearly defined; one of them shot out with a velocity of 190 kilometres per second and attained a height of 1′ 25″, almost six times the diameter of the Earth." On other occasions perfectly straight rays were projected with a still more startling velocity. Quoting again from Secchi: "The first of July we saw some which in four minutes ran up to 2′ 20″." Now is it conceivable that a gas shooting up from a gaseous Sun can take the form of jets which remain clearly outlined and perfectly straight up to a distance equal to ten times the diameter of the Earth? Can it be admitted that there are on the gaseous and cloudy surface of the Sun, holes with resisting walls† drawing out the ejected gas into threads? Is it possible that a streamer of gas thrown obliquely into the solar atmosphere can there preserve its primitive form with "definite outlines" to a distance of many terrestrial radii? Has such a filament no appreciable force of expansion, even in the rarified upper layers of the atmosphere? Does it meet with no sensible resistance in this gaseous medium? And is it no longer subject to the least influence of solar gravitation, as appears to be the case, since the filament, although much inclined, remains "perfectly straight" over a length equal to twenty of the Earth's radii.

If at other times streamers of incandescent gas twist into spirals or curve gently back again toward the surface, still (sharply defined as before) it is not any easier to see in them the portrayal of an actual movement. All these filiform prominences, straight or curved, are of the same general type as the filamentary clouds of our own atmosphere—of the same type also as those slender jets which one sees so often‡ in those clouds completely detached from the chromosphere, which we have already considered above,

* Secchi, *le Soleil* II, p. 59.
† Lockyer, *Chem. of the Sun*, p. 423. Young, *The Sun*, p. 169.
‡ Secchi, *le Soleil*, II, p. 69.

and which by common consent have long been considered as "quiescent prominences."

5. *The improbable velocities of the supposed movements.*— These velocities are not only improbable in reaching such marvel ous rates of several hundreds or even of more than a thousand kilometers per second:* but they are not less so when they ceaselessly and capriciously change their rate and direction, now rapidly diminishing, now as rapidly augmenting. Though Ranyard has attempted to demonstrate that the movement of a prominence observed by Young, Oct. 7, 1880, seemed to agree in some small measure with that of a projectile restrained in its course by the gravitation of the sun,† there have been few observations of this kind, while I know of many where a careful study of the velocities‡ showed them to be absolutely incompatible with every hypothesis of an eruption, of an explosion, or even of any form of electric repulsion. It is quite remarkable too that spectroscopic investigations of small eruptions, of 20″ for instance, show in them now and then great velocities (426 kilometres per second) while at other times no motion in the line of sight is observed in enormous eruptions like that the third of October last.§

6. *The very brief duration of some prominences, their rapid changes of form and their sudden extinction,* at times in two minutes. This extinction is the more remarkable that the most slender incandescent jets which can be distinguished are nevertheless 200 or 300 k. in thickness.¶ Secchi, Zöllner, Young, Lockyer and Fényi** have given many descriptions of these solar *dissolving views.* The rapidity of these changes to the sight is such that Secchi himself, after describing them, adds: "The cloudy masses (of the prominences) flash out so quickly and again so quickly dissolve that one is compelled to see in them a momentary transformation rather than a real transportation of ponderable matter.††

7. *The perfect quiet* which is observed (A) in the photosphere (sometimes even where it is unspotted‡‡) at a place bordering on

* Fényi, *Mem. d. Soc. d. Spettrosc. Ital*, Vol. XXI (1892), Rapport sur les movements aussi singuliers qu'extraordinaires d'une protuberance observée le 17 Juin, 1891.

† Ranyard, *Monthly Notices*, Dec. 1880.

‡ Fényi, *Protuberanzen beob. in J. 1887*, pp. 19-20.

§ Fényi, *loc. cit.* p. 14. See also on p. 23 the difficulties of interpreting velocities in the line of sight, such as those exhibited by the enormous prominence of July 1, 1887.

¶ Secchi, *le Soleil* II, p. 70.

** *Loc. cit.*, p. 23.

†† Secchi, *le Soleil*, II. p. 108. Pl. E—figs. 5, 6. Pl. H—figs. 1, 3, 5, 7, 9, 11. Young, *The Sun*, figs. 62, 63. Lockyer, *Solar Physics*, figs. 92, 93; 135, 136.

‡‡ Fényi, Deux eruptions considérables 5 et 6 Sept. 1888. *Mem. d. Soc. Spettros. Ital.* XXIII. (1889).

a gigantic prominence;* (*B*) in the solar atmosphere at a place even where several minutes previously there had occurred a terrific eruption;† (*C*) in the small clouds floating in the solar atmosphere and not stirring although in the immediate neighborhood of an extraordinary eruption.‡

The quiet maintenance of quiescent prominences often for so long a time is another proof of great atmospheric calm. But how can such a calm be produced if, according to Secchi, there are during a maximum period at least two hundred centres of eruptions in full activity on the surface of the Sun,§ and if we believe with Young‖ that the Sun is always surrounded by flames innumerable.

8. *The sudden origin of metallic prominences at transcendent speed without visible connection with the distant chromosphere.* In this way appeared the great prominenceof June 17, 1891, showing at once an upward velocity of 485 k. per second, and a motion of 890 k. in the line of sight.¶ "This time, however," says Fényi, "the masses in commotion were not observed to leave the surface, notwithstanding the fact that the same locality was continually watched." "In all probability," he adds, "the forces which occasioned the motion described originated at a certain height and suddenly acted upon masses which they there encountered." Do not such observations perfectly agree with my theory of the prominences, namely, that they are a sort of faint glow (*lueur*) originating spontaneously in quiescent matter? Here is still another observation of the same kind, mentioned by Fényi as a "marvellous fact." It is the sudden appearance, by no means rare, of great motion in the line of sight alone;** motions for example, which, although continuing with a velocity of 150 k. a second during half an hour, produce nevertheless no displacement in the position of the prominence, and cannot possibly be attributed to currents in the matter of which the Sun is composed.

Rapidly moving isolated jets which appear so often and so suddenly, the so-called eruptive prominences seem to spring into existence spontaneously in the same manner. If the prominences

* *Loc. cit.*

† Trouvelot, *l'Astr.*, IV, p. 441. Lockyer, *Chem. of Sun*, p. 415. Fényi, *Comptes rendus* 108, p. 889.

‡ Fényi: *Memorie*, Vol. XXI, (1892), Sur une protuberance d'une hauteur énorme observée le 5 Mai à Kalocsa.

§ Secchi, *le Soleil*, II, p. 80.

‖ Young, *The Sun*, p. 147.

¶ Fényi, *Mem.* XXI, 1892, Rapport sur les movements aussi singuliers qu' extraordinaires d'une protuberance observée le 17 Juin, 1891. Tacchini, *Compt. rend.*, 9 Janv. 1893. N. F. Miller, ASTRONOMY AND ASTRO-PHYSICS, 1892, p. 615.

** Fényi, *loc. cit.* Mem. XX, 1891.

with ragged outlines result from the superposition of several prominences in the line of vision,* the difficulty of explaining their sudden simultaneous appearance as the effect of true eruptions is all the greater; since, if it is already difficult to admit that a single prominence may have an ultimate chromospheric connection concealed by some cooled opaque mass, that difficulty is still greater when several contemporary eruptions require this same hypothesis at the same time. The existence of these connections with the chromosphere is, to say the least, very doubtful. The argument runs like this, "These connections are surely there, but they cannot be seen because they are veiled by a cooler opaque mass which itself is invisible." Such an argument is not very convincing.

Besides the arguments which I have advanced against the hypothesis of solar eruptions, I have still another which, of itself, seems to me much more important than all the others together. The principal fact, already referred to, is that it is only necessary *to be freed from that sterile hypothesis, to accept a plausible chemical explanation of the principal solar phenomena.* In a comparatively quiet Sun the motions of even the largest prominences cease to be mysterious. And not only do the prominences then become infinitely more comprehensible, but it is soon seen that the cause of the prominences is also that of the spots, and of the coronal rays as well, and that this common cause is of such a nature as to distribute these phenomena periodically and, in parallel zones, over the surface of the Sun.

Such are the recent explanations which I have developed in my Memoir mentioned above. If the discussion which I have given them here is necessarily but brief, I hope nevertheless, to give it some new interest by an examination of the numerous observations which have been made without cessation since the publication of my Memoir, tending in general (I trust it will be seen) to confirm my theory.

ON THE THEORY OF STELLAR SCINTILLATION.†

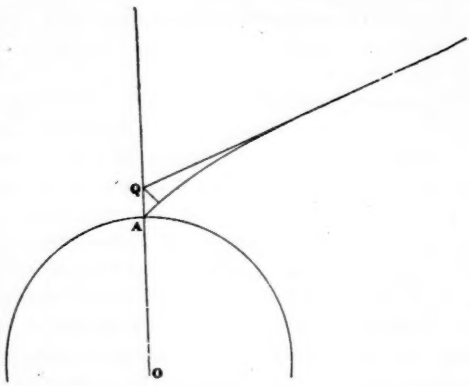
LORD RAYLEIGH.

A complete investigation of atmospheric refraction can only be made upon the basis of some hypothesis as to the distribution of

* Ranyard, *Knowledge*, Feb. 1893.

† Continued from p. 845, No. 119.

temperature; but, as has already been hinted, a second approximation to the value of refraction can be obtained independently of such knowledge and without difficulty. In Laplace's elaborate investigation it is very insufficiently recognized, if indeed it be recognized at all, that the whole difficulty of the problem depends upon the curvature of the Earth. If this be neglected, that is if the strata are supposed to be plane, the desired result follows at once from the law of refraction, without the necessity of knowing anything more than the condition of affairs at the surface.



For in virtue of the law of refraction,

$$\mu \sin \theta = \text{constant};$$

so that if θ be the apparent zenith distance of a star seen at the earth's surface, and $\delta\theta$ the refraction, we have at once

$$\mu_0 \sin \theta = \sin (\theta + \delta\theta), \tag{19}$$

from which the refraction can be rigorously calculated. If an expansion be desired,

$$\begin{aligned} \delta\theta &= \sin \delta\theta = \tan \theta \,(\mu_0 - \cos \delta\theta) \\ &= (\mu_0 - 1) \tan \theta \{1 + \tfrac{1}{2}(\mu_0 - 1) \tan^2 \theta\} \end{aligned} \tag{20}$$

is the second approximation.

When the curvature of the Earth is retained, so that the atmospheric strata are supposed to be spheres described round O, the centre of the Earth the appropriate form of the law of refraction is

$$\mu p = \text{constant}.$$

Thus, if A be the point of observation at the Earth's surface where the apparent zenith distance is θ, and if the original direction of the ray outside the atmosphere meet the vertical OA at the point Q,

$$\mu_0 \,.\, OA \,.\, \sin\theta = OQ \,.\, \sin(\theta + \delta\theta);$$

or if $OA = a$, $AQ = c$,

$$\mu_0 a \sin\theta = (a + c)\sin(\theta + \delta\theta) \qquad (21)$$

If c be neglected altogether, we fall back upon the former equations (19), (20). For the purposes of a second approximation c, though it cannot be neglected, may be calculated as if the refraction were small, and the curvature of the strata negligible. If η be the whole linear deviation of the ray due to the refraction,

$$c = \eta/\sin\theta, \qquad (22)$$

and, as in (16),

$$\eta = (\mu_0 - 1)\, l \sin\theta/\cos^2\theta, \qquad (23)$$

so that

$$c = \frac{(\mu_0 - 1)l}{\cos^2\theta} \qquad (24)$$

By equations (21), (24) the value of $\delta\theta$ may be calculated from the trigonometrical tables without further approximation.

To obtain an expansion. we have

$$\delta\theta = \sin\delta\theta = \frac{\mu_0 \tan\theta}{1 + c/a} - \tan\theta\cos\delta\theta$$

$$= \tan\theta\left\{\frac{\mu_0}{1 + c/a} - 1\tfrac{1}{2}(\delta\theta)^2\right\}$$

$$= (\mu_0 - 1)\tan\theta\left\{1 - \frac{\mu_0 c}{(\mu_0 - 1)a} + \tfrac{1}{2}(\mu_0 - 1)\tan^2\theta\right\}$$

$$= (\mu_0 - 1)\left(1 - \frac{l}{a}\right)\tan\theta$$

$$- (\mu_0 - 1)\left(\frac{l}{a} - \frac{\mu_0 - 1}{2}\right)\tan^3\theta \qquad (25)$$

To this order of approximation the refraction can be expressed in terms of the condition of things at the earth's surface, and (25) is equivalent to an expression deduced at great length by Laplace.

From the value of l already quoted, and $a = 6.3709 \times 10^8$ centim., we get

$$l/a = .0012541 \qquad (26)$$

If further we take as the value under standard conditions for the line D

$$\mu_0 - 1 = .0002927, \qquad (27)$$

we find as the refraction expressed in seconds of arc

$$\delta\theta = 60''.29 \tan\theta - 0''.06688 \tan^3\theta \qquad (28)$$

In (28) θ is the apparant zenith distance, and it should be understood that the application of the formula must not he pushed too close to the horizon. If the density of the air at the surface of the earth differ from the standard density (0° and 760 millim.) the numbers in (28) must be altered proportionately. It will be observed that the result has been deduced entirely *à priori* on the basis of data obtained in laboratory experiments.

It may be convenient for reference to give a few values calculated from (28) of the refraction, and of the dispersion, reckoned at $\frac{1}{40}$ of the refraction.

Apparent zenith distance.	Refraction.	Dispersion (B to H).
°	′ ″	″
0	0.0	0.0
20	21.9	.5
40	50.5	1.3
45	1 0.2	1.5
60	1 40.1	2.5
70	2 44.2	4.1
75	3 41.5	5.5
80	5 29.7	8.2
85	9 49.2	14.7

The results of the formula (28) agree with the best tables up to a zenith distance of 75°, at which point the value of the second term is 3″.5. For 85° the number usually given is 10′ 16″, and for 90° about 36′; but at these low altitudes the refraction is necessarily uncertain on account of irregularities such as those concerned in the production of mirage.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Observatory of the University of Chicago, Chicago, U. S. A. Authors of papers are requested to refer to last page for information in regard to illustrations, reprint copies, etc.

The New Telescope of the Dudley Observatory.—At the November meeting of the National Academy at Albany, Professor Hastings read a paper on a new form of telescope objective, as applied to the 12-inch equatorial of the Dudley Observatory. The objective was made by Mr. Brashear, and its novel features were described in the December number of this journal 1892. Professor Boss expresses much

satisfaction with its performance, which he has already tested quite thoroughly. The formal opening of the new Observatory was attended by members of the Academy, and the chief address was read by Professor Newcomb.

Shadows of Jupiter's Satellites.—In No. 31 of the Publications of the Astronomical Society of the Pacific, Professor Schaeberle gives a formula for determining at any time the apparent shape of the shadow of a satellite on the surface of Jupiter. The elongated forms often observed are accounted for on simple geometrical principles. In the case of the first satellite the length of the apparent shadow may be more than twice its breadth. Anomalous outlines may be caused by differences in the brilliancy of the surface where the shadow is projected on it.

Jupiter in 1893.—The red spot on Jupiter is now extremely faint, differing so little in color and brightness from the surface in its neighborhood that it can barely be recognized. The outline is still a fairly true ellipse which is somewhat darker at the extremities of the major axis than elsewhere, the darkest place being at the following end. In a small telescope this darkening causes the spot to appear unduly elongated. The color of the spot is a very pale pink.

Interesting detail appears in the northern hemisphere, particularly in the northern equatorial belt. A series of very small black spots is seen in a latitude of about 50°.

Notes on Small Stars.—In No. 31 of the Publications of the Astronomical Society of the Pacific, there is a note by W. W. C. on a small red star DM. + 36° 4025, which is supposed not to have been observed before. DM. + 36° 4028 belongs to type II b, and should be excluded from the list of stars of type III b, in which it is placed by Scheiner.

We believe that the red star was noted some years ago by Espin.

A New Catalogue of Colored Stars.—A valuable addition to astro-physical literature is a catalogue of colored stars, with special reference to spectral types, just published at Kiel in the familiar print of the *Astronomische Nachrichten.* The catalogue, by Herr Friedrich Krüger, had its origin in an essay on colored stars which won a prize offered by the faculty of the University, and which was subsequently enlarged into its present form and printed as Vol. VIII of the Publications of the Kiel Observatory. It contains all stars north of 23° South declination which are of a yellow or reddish color, or which are remarkable through the existence of absorption bands in their spectra, and as original sources were always consulted in the compilation, and moreover as every star within reach of the Kiel 8½-inch refractor was specially examined with a spectrocsope, it embodies a large amount of research.

The introduction contains an account of previous catalogues; the work of different observers—their instruments and methods; an explanation of the different systems of stellar classification; a description of Herr Krüger's own observations and of the arrangement of the catalogue (in which the index of abbreviations is practically a bibliography of the literature of colored stars), and other matter of much interest. In the catalogue are given the number of each star, the number in the Durchmusterung and in the Birmingham catalogues, the right ascension and declination for 1900 with the amount of precession, the magnitude

according to the Durchmusterung, the Harvard Photometry and the Kiel observations, the color on a scale of 0 for pure white and 10 for pure red, the type of spectrum according to Secchi's classification and in the system of the Draper Catalogue, the principal observers, and more or less extended notes. At the end is a fine lithographed plate of Secchi's spectral types, in which, however, contrary to recent usage, the red end of the spectrum is placed on the left.

Stars of Class I c (Vogel) are not included, nor are most of the Wolf-Rayet stars, although probably all the stars of the latter class are characterized by strong absorption bands which might give them claims to admission. We take pleasure in calling attention to the value of this catalogue, to which further interest is added by the novelty of spectroscopic observations in the series of Kiel Observatory publications.

The Nature of the Sun's Photosphere.—An interesting discussion of the above-mentioned subject is contained in the last two numbers of *Knowledge*, originating in some remarks made by Professor Arthur Smithells in a lecture on "Flame," delivered before the British Association at Nottingham. Professor Smithells said, "The Earth is known to be a cooling body, and also an oxidized body. At one time it must have been too hot for the oceans to have existed upon it in a liquid state, and at a still more remote period all the waters of the Earth probably existed as an enormous gaseous envelope of uncombined hydrogen and oxygen. Chemistry forces us to imagine an intervening time at which this oxygen and hydrogen would begin to combine. During that period, huge cosmical flames would rend the atmosphere. The steam formed would descend to the hotter strata of the pre-geologic atmosphere, would be dissociated and sent forth again to combine in the upper atmosphere, causing an incessant celestial pyrotechny;" hence in the opinion of the lecturer, the Earth at that remote period must have had an appearance somewhat resembling that of the Sun at the present time.

Mr. Ranyard is not able to adopt this view as to the constitution of the solar photosphere, but thinks that perhaps too little attention has been paid to the possibility of explosive chemical combinations in the Sun. Without them it is difficult to account for the violent uprushes of matter observed in the chromosphere, and the greatly extended streamers of the corona. Luminous gas would however scarcely account for the intense brilliancy of the photosphere, and we must look to incandescent solid particles as the source of its light. We are led to conclude "that the light of the photosphere must be due to the brilliant incandescence of the most refractory substances present in the Sun, at a level where they are just on the point of being driven into vapor." The solar atmosphere at the photospheric level must be excessively tenuous, but it is not necessary to assume that the condensed particles float in it as clouds of condensed water vapor float in the atmosphere of the Earth. Each particle would be retarded in its descent by the reaction produced by vaporization on the side turned toward the Sun. At a certain level which might be at a great height the particles would tend to accumulate, although other solar phenomena show that the denser parts of the Sun are not very far below the photosphere.

Miss Clerke raises the objection that if photospheric temperatures are determined by the boiling-points of the most refractory substances present, as they would be according to Mr. Ranyard's explanation, a very narrow range of diversity can be allowed to stellar emissive power, while such data as we can obtain show that the range is very great. This assumes that all stars are composed of nearly the same materials, a point which Mr. Ranyard cannot allow. The range

of density may be very great. In the Hercules cluster the stars are perhaps very little denser than the streams of nebulous matter in which they are situated, and hence their density is only something like a thousand millionth part of that of the Sun.

Mr. Evershed points out that gases cooling down from a temperature above that of dissociation could not combine with explosive violence, as they are already at the temperature which represents the energy of their chemical combination. Union would follow the gradual fall of temperature, but it would be slow on that account, and no explosion would result. To this Professor Smithells replies that examples of false equilibrium are common in chemistry, and that the gases might be cooled far below the dissociation point in certain regions without combining; while he disclaims any intention to herald a new theory of the Sun, he thinks that *a priori* thermo-chemical reasoning should be used with caution, and that one must not rashly exclude chemical action as a factor in solar phenomena.

In connection with this interesting discussion we may observe that Mr. Ranyard's views as to the source of the photospheric light are quite similar to those of Professor Hastings, as set forth in his "Theory of the Constitution of the Sun," printed in the Proceedings of the American Academy, 1880. The substance which by its precipitation from the gaseous state causes the intense incandescence of the photosphere was regarded by Professor Hastings as some member of the carbon group, and most probably silicon. The theory was shown to account very satisfactorily for the sudden brightening at the inner ends of the penumbral filaments in a sun-spot.

Preliminary Note on the Spectrum of the Orion Nebula.—It has heretofore been assumed that the visible spectrum of the Orion Nebula exhibits an essential and fundamental sameness. This view differs so radically from the results of my observations that I desire to present the following preliminary note on the subject.

The relative intensities of the three principal lines vary within wide limits for the different parts of the nebula. In the dense region adjacent to the Trapezium, the intensities of the lines (wave-lengths 501, 496 and 486) are represented approximately by the ratios 4 : 1 : 1. For many regions of medium intensity the lines at 501 and 486 are about equally bright. Many of the faint portions on the south and west borders of the nebula give a spectrum in which the third line ($H\beta$ 486) is brighter than the first (501). In particular, the isolated portion north-east of the Trapezium (surrounding the star *Bond* No. 734) gives a spectrum in which the third line is at least five times as intense as the first.

The relative intensities of the first and third lines change rapidly as the slit is moved over the nebula. It often happens that of two adjacent parts in the short slit at the same time, one gives a spectrum in which the first line is stronger than the third, and the other a spectrum in which the third is stronger than the first.

The ratio of the intensities of the first and second lines remains practically constant at 4 : 1. In nearly the whole nebula the second line is fainter than the the third.

In general the hydrogen line (486) is relatively very strong in the faint outlying regions. It is relatively stronger in the Orion nebula than in any other nebula I have examined, except the planetary nebula SD. — 12° 1172.*

W. W. Campbell.

Mt. Hamilton, 1893, Oct. 18.

* This nebula was discovered and the strong $H\beta$ line noticed by Mrs. M. Fleming on the Harvard College plates. See *Astr. Nach.* No. 3049.

Electro-Magnetic Theory of the Sun's Corona.—I feel that I am called upon to make a few statements bearing upon Dr. Hermann Ebert's paper, "Electro Magnetic Theory of the Sun's Corona," which appeared in the November number of ASTRONOMY AND ASTRO-PHYSICS.

An electrical theory of the Sun's corona was suggested to my mind by my experiments on electrical discharges through poor vacua (*Amer. Jour. Sc.*, April, 1892, p. 266) and on coronoidal discharges (*Amer. Jour. Sc.*, (3) 43, p. 463, 1892; ASTRONOMY AND ASTRO-PHYSICS, May, 1892, paper read before the National Academy of Sciences, Washington, April 22nd, 1892, and I did not hesitate to express my belief in the scientific value of this theory; in fact, I was so fascinated by it that I put myself considerably out of the way to arrange my experiments on electrical discharges in such a way as to bring out forcibly the resemblance between these discharges and the solar corona.

Subsequent experiments, which I did not publish, encouraged me more and more to consider seriously the Electrical Theory of the Solar Corona, and at the request of Professor J. K. Rees, of Columbia College, I read a paper, on Dec. 5th, 1892, before the New York Academy of Sciences, on the Electro Magnetic Theory of the Solar Corona. This paper I abstracted for the Transactions of the Academy; a reference to it and the electro-magnetic theory it contains was made in a letter which I addressed to the Editor of ASTRO-PHYSICS and was published in your esteemed journal, May, 1893.

A comparison of Dr. Ebert's theory and mine will show that they are identical. Dr. Ebert's reference to my experimental investigations in this matter seems to indicate that he claims the priority of suggesting this theory, or, at any rate, the priority of experimenting upon such electrical discharges through gases which would tend to support this theory. So far as I can see, he has no ground on which he could support this claim, if he really makes it at all. For, in the first place I was very much ahead of him in point of time of publication; in the second place I commenced my experimental investigations early in 1891 (see *Amer. Jour. Sc.*, June, 1892, p. 465), and Dr. Ebert, according to his own statement in the paper mentioned above, did not commence any sooner.

M. I. PUPIN.

Columbia College, New York, Nov. 21, 1893.

New Variables.—Mrs. Fleming has detected a new variable star on the Harvard plates in R. A. $15^h\ 22^m\ 16^s$, Dec. — 50° 14′. Its magnitude on July 10 was 7.0.

According to a Wolsingham circular, an anonymous red star in R. A. 20^h 46′ 59^s, Dec. + 46° 47′, is variable. It was of the 9.1 magnitude on Aug. 21, and is now fading. (This star is not in the new catalogue of Krüger, which is mentioned in another note.)

Professor W. H. Pickering is now at Cambridge, Mass. He will, for some time to come, be occupied in preparing the observations made at Arequipa, South America for publication.

G. W. Hanchett, Hyde Park, Mass., is fitting up a small Observatory aud is about to order a 6½-inch telescope. His attention will be given largely to observation of double stars.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR JANUARY.

Mercury having been at greatest western elongation Dec. 14 will in January be too close to the Sun for observation. He will be at superior conjunction Jan. 29 at $6^h\ 36^m$ A. M.

Venus which has been such a brilliant object in the early evening sky during the past month will be still more brilliant during the first part of January. This planet will attain its maximum brilliancy on Jan. 10 when the light will be 218 as compared with 145 on December 1. The position of Venus is becoming a little more favorable for observation in northern latitudes, as the planet moves northward in declination. Venus and the crescent Moon will be in conjunction on the morning of Jan. 10 and the two will form a pretty pair on that evening and the preceding.

Mars will be morning planet during January, visible in the southeast after five o'clock. The low altitude will prevent good observations in our latitude, but south of the equator something may be done in the study of the surface markings of the planet. Mars and the waning Moon will be in conjunction on the morning of Jan. 3, the latter passing 4° south of the former.

Jupiter will be in excellent position for observation during the first half of the night in January. The planet will be stationary among the stars of Taurus on Jan. 15, after which it will move slowly eastward. The "great red spot" was well seen by us with the 16-inch telescope on the night of Oct. 31. Its centre was on the central meridian of Jupiter at $11^h\ 31^m$, Central time, as near as we could estimate. This time agrees closely with that predicted by Mr. Marth. The spot was seen without difficulty although the color was quite faint. The color was exactly the same as that of the belt just to the south of it, and the two objects merged into one another without the slightest change in intensity of color. The outline of the spot seems to be the same as in past years, except as stated above, that its southern edge is merged into the belt. There seemed to be two white clouds over the central portions of the spot, the following of the two being the larger. The seeing was excellent during this observation and much of very minute detail was seen in all the belts.

Saturn is getting into better position for observation in the morning but the majority of observers will prefer to wait two or three months until the planet is visible in the evening. Saturn will be at quadrature, 90° west from the Sun, Jan. 14. Saturn is in the constellation Virgo a little northeast of Spica and is moving very slowly eastward. The Moon will be 4° south of Saturn at noon Jan. 27.

Uranus is in the constellation Libra a little way east of the star α. It is not yet in very good condition for observation in our latitude.

Neptune having passed opposition in December will be in excellent position for observation in January. It will move very slowly westward during the month, the position January 1 being a little more than ⅓ of the distance on a straight line from ι to ϵ Tauri. There is no star of equal brightness within a radius of 1°.

PLANET TABLES FOR JANUARY.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Jan. 5	18 06.0	− 24 00	6 44 A. M.	11 04.9 A. M.	3 25 P. M.
15	19 14.0	− 23 53	7 12 "	11 33.3 "	3 54 "
25	20 24.1	− 21 26	7 31 "	12 04.0 P. M.	4 37 "
			VENUS.		
Jan. 5	22 01.3	− 11 39	9 43 A. M.	2 59.5 P. M.	8 16 P. M.
15	22 18.6	− 8 06	9 06 "	2 37.6 "	8 09 "
25	22 23.6	− 5 16	8 21 "	2 03.2 "	7 46 "
			MARS.		
Jan. 5	16 04.4	− 20 33	4 26 A. M.	9 03.6 A. M.	1 41 P. M.
15	16 33.2	− 21 49	4 22 "	8 53.0 "	1 24 "
25	17 02.6	− 22 47	4 16 "	8 43.0 "	1 10 "
			JUPITER.		
Jan. 5	3 17.6	+ 17 16	1 00 P. M.	8 15.0 P. M.	3 30 A. M.
15	3 17.0	+ 17 16	12 20 "	7 35.0 "	2 50 "
25	3 17.7	+ 17 22	11 41 A. M.	6 56.3 "	2 12 "
			SATURN.		
Jan. 5	13 34.3	− 7 12	12 59 A. M.	6 33.8 A. M.	12 09 P. M.
15	13 35.8	− 7 19	12 22 "	5 56.1 "	11 30 A. M.
25	13 36.8	− 7 21	11 43 P. M.	5 17.7 "	10 52 "
			URANUS.		
Jan. 5	14 48.6	− 15 49	2 49 A. M.	7 48.1 A. M.	12 47 P. M.
15	14 49.9	− 15 55	2 12 "	7 10.1 "	12 09 "
25	14 51.0	− 15 59	1 33 "	6 31.8 "	11 30 A. M.
			NEPTUNE.		
Jan. 5	4 39.8	+ 20 36	2 04 P. M.	9 36.9 P. M.	5 09 A. M.
15	4 39.0	+ 20 35	1 24 "	8 56.8 "	4 29 "
25	4 38.3	+ 20 34	12 44 "	8 16.8 "	3 59 "
			THE SUN.		
Jan. 5	19 07.1	− 22 34	7 38 A. M.	12 05.8 P. M.	4 34 P. M.
15	19 50.5	− 21 02	7 35 "	12 09.8 "	4 45 "
25	20 32.8	− 18 50	7 27 "	12 12.6 "	4 58 "

Phases and Aspects of the Moon.

		Central Time. d	h m
Apogee	Jan.	5	6 00 A. M.
New Moon	"	6	9 07 P. M.
First Quarter	"	14	6 09 P. M.
Perigee	"	20	9 12 A. M.
Full Moon	"	21	9 12 A. M.
Last Quarter	"	28	10 51 A. M.

Occultations Visible at Washington.

Date 1894.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	Angle f'm N pt. °	EMERSION Washington M. T. h m	Angle f'm N pt. °	Duration. h m
Jan. 11	χ Aquarii	5½	6 52	89	7 48	198	0 56
18	136 Tauri	5	16 16	105	17 05	266	0 49
19	W. VI, 1656	8	17 08	140	17 48	247	0 40
20	e Geminorum	6	4 49	110	5 38	254	0 49
20	ω^1 Cancri	6	12 19	83	13 25	319	1 06
20	ω^2 Cancri	6	12 54	129	14 04	273	1 10

Phenomena of Jupiter's Satellites.

Central Time.

	h m			
Jan. 5	12 07	A. M.	II	Tr. In.
	12 18	"	I	Tr. In.
	1 22	"	I	Sh. In.
	2 13	"	II	Sh. In.
	2 28	"	II	Tr. Eg.
	2 30	"	I	Tr. Eg.
	3 34	"	I	Sh. Eg.
	9 32	P. M.	I	Oc. Dis.
6	12 47	A. M.	I	Ec. Re.
	6 38	P. M.	II	Oc. Dis.
	6 46	"	I	Tr. In.
	6 48	"	III	Oc. Dis.
	7 51	"	I	Sh. In.
	8 37	"	III	Oc. Re.
	9 58	"	I	Tr. Eg.
	10 03	"	I	Sh. Eg.
	11 05	"	II	Ec. Re.
	11 18	"	III	Ec. Dis.
7	12 57	A. M.	III	Ec. Re.
	4 00	P. M.	I	Oc. Dis.
	7 16	"	I	Ec. Re.
8	4 32	"	I	Sh. Eg.
	5 54	"	II	Sh. Eg.
12	11 23	"	I	Oc. Dis.
13	2 43	A. M.	I	Ec. Re.
	8 35	P. M.	I	Tr. In.
	9 03	"	II	Oc. Dis.
	9 46	"	I	Sh. In.
	10 27	"	III	Oc. Dis.
	10 48	"	I	Tr. Eg.
	11 25	"	II	Oc. Re.
	11 26	"	II	Ec. Dis.
	11 58	"	I	Sh. Eg.
14	12 19	A. M.	III	Oc. Re.
	1 41	"	II	Ec. Re.
	5 50	P. M.	I	Oc. Dis.
	9 12	"	I	Ec. Re.
15	3 03	"	I	Tr. In.
	3 49	"	II	Tr. In.
	4 14	"	I	Sh. In.
	5 15	"	I	Tr. Eg.
	6 11	"	II	Tr. Eg.
	6 11	"	II	Sh. In.
Jan. 15	6 27	P. M.	I	Sh. Eg.
	8 33	"	II	Sh. Eg.
17	5 22	P. M.	III	Sh. In.
	7 15	"	III	Sh. Eg.
20	10 26	"	I	Tr. In.
	11 30	"	II	Oc. Dis.
	11 41	"	I	Sh. In.
21	12 39	A. M.	I	Tr. Eg.
	7 42	P. M.	I	Oc. Dis.
	11 08	"	I	Ec. Re.
22	4 54	"	I	Tr. In.
	6 10	"	I	Sh. In.
	6 21	"	II	Tr. In.
	7 07	"	I	Tr. Eg.
	8 22	"	I	Sh. Eg.
	8 43	"	II	Tr. Eg.
	8 50	"	II	Sh. In.
	11 12	"	II	Sh. Eg.
23	5 37	"	I	Ec. Re.
24	5 35	"	II	Ec. Re.
	6 09	"	III	Tr. Eg.
	9 24	"	III	Sh. In.
	11 18	"	III	Sh. Eg.
28	12 19	A. M.	I	Tr. In..
	1 36	"	I	Sh. In.
	2 00	"	II	Oc. Dis.
	9 35	P. M.	I	Oc. Dis.
29	1 04	A. M.	I	Ec. Re.
	6 47	P. M.	I	Tr. In.
	8 05	"	I	Sh. In.
	8 54	"	II	Tr. In.
	8 59	"	I	Tr. Eg.
	10 18	"	I	Sh. Eg.
	11 17	"	II	Tr. Eg.
	11 29	"	II	Sh. In.
30	1 50	A. M.	II	Sh. Eg.
	4 04	P. M.	I	Oc. Dis.
	7 33	"	I	Ec. Re.
31	5 39	"	II	Oc. Re.
	5 55	"	II	Ec. Dis.
	8 03	"	III	Tr. In.
	9 11	"	II	Ec. Re.
	10 03	"	III	Tr. Eg.

Configuration of Jupiter's Satellites at 9h Central Time, for an Inverting Telescope.

Jan.		Jan.		Jan.	
1	2 1 ○ 3 4	12	3 2 4 1 ○	23	4 2 ○ 1 3
2	2 ○ 3 1 4	13	♃ 3 ○ 4 ●	24	4 1 3 ○ 2
3	3 1 ○ 2 4	14	● ○ 2 3 4	25	4 3 ○ 1 2
4	3 4 ○ 2 1	15	1 2 ○ 3 4	26	4 3 2 1 ○
5	3 4 2 1 ○	16	2 ○ 1 3 4	27	4 3 2 ○ 1
6	4 1 ○ 3 ●	17	1 3 ○ 2 4	28	4 1 ○ 3 2
7	4 ○ 1 2 3	18	3 ○ 1 2 4	29	♃ 1 4 ○ 3
8	4 1 2 ○ 3	19	3 2 1 ○ 4	30	2 ○ 1 4 3
9	4 2 ○ 3 1	20	3 2 ○ 1 4	31	♃ 1 ○ 2 4
10	4 3 1 ○ 2	21	4 ○ 3 2 ●		
11	3 4 ○ 2 1	22	4 1 2 ○ 3		

Approximate Times when the Great Red Spot will pass the Central Meridian of Jupiter.

		h m		h m		h m
Jan.	2	12 40 A. M.	12	6 48 P. M.	22	5 06 P. M.
	2	8 31 P. M.	14	12 36 A. M.	23	10 53 "
	3	4 23 "	14	8 27 P. M.	24	6 45 "
	4	10 10 "	15	5 18 "	26	12 31 A. M.
	5	6 01 "	16	10 06 "	26	8 24 P. M.
	6	11 48 "	17	5 57 "	27	4 15 "
	7	7 40 "	18	11 44 "	28	10 02 "
	9	1 27 A. M.	19	7 36 "	29	5 54 "
	9	9 18 P. M.	21	1 22 A. M.	30	11 41 "
	10	5 10 "	21	9 14 P. M.	31	7 33 "
	11	10 57 "				

Ephemeris of the Fifth Satellite of Jupiter.

Approximate Central Times of Greatest Elongations.

		Eastern Elongation.	Western Elongation.			Eastern Elongation.	Western Elongation.
Jan.	1	9 39 P. M.	3 38 A. M.	Jan.	17	8 16 P. M.	2 15 A. M.
	3	9 29 "	3 28 "		19	8 06 "	2 05 "
	5	9 18 "	3 17 "		21	7 55 "	1 54 "
	7	9 08 "	3 07 "		23	7 45 "	1 44 "
	9	8 57 "	2 56 "		25	7 35 "	1 34 "
	11	8 47 "	2 46 "		27	7 25 "	1 24 "
	13	8 37 "	2 36 "		29	7 15 "	1 14 "
	15	8 26 "	2 25 "		31	7 05 "	1 04 "

Elongations of the Satellites of Saturn.

(The western elongations will be found approximately half way between the eastern and other positions may be easily interpolated.)

MIMAS.

		h		
Jan.	2	5.7	A. M.	W
	3	4.3	"	W
	4	2.9	"	W
	9	7.3	"	E
	10	6.0	"	E
	11	4.6	"	E
	12	3.2	"	E
	13	1.8	"	E
	17	7.6	"	W
	18	6.2	"	W
	19	4.9	"	W
	20	3.5	"	W
	21	2.1	"	W
	25	7.9	"	E
	26	6.5	"	E
	27	5.1	"	E
	28	3.7	"	E
	29	2.3	"	E

ENCELADUS.

Jan.	2	2.2	A. M.	E
	3	11.9	"	E
	4	7.9	P. M.	E
	6	4.8	A. M.	E
	7	1.7	P. M.	E
	8	10.6	"	E
	10	7.5	A. M.	E
	11	4.3	P. M.	E
	13	1.2	A. M.	E
	14	10.1	"	E
	15	7.0	P. M.	E
	17	3.9	A. M.	E
	18	12.7	P. M.	E
	19	9.6	P. M.	E

ENCELADUS CONT.

		h		
Jan.	21	6.5	A. M.	E
	22	3.4	P. M.	E
	24	12.3	A. M.	E
	25	9.1	"	E
	26	6.0	P. M.	E
	28	2.9	A. M.	E
	29	11.8	"	E
	30	8.7	P. M.	E
Feb.	1	5.5	A. M.	E

TETHYS.

Jan.	2	11.7	P. M.	E
	4	9.0	"	E
	6	6.3	"	E
	8	3.6	"	E
	10	12.9	"	E
	12	10.2	A. M.	E
	14	7.5	"	E
	16	4.8	"	E
	18	2.1	"	E
	19	11.4	P. M.	E
	21	8.7	"	E
	23	6.0	"	E
	25	3.3	"	E
	27	12.6	"	E
	29	9.9	A. M.	E
	31	7.2	"	E

DIONE.

Jan.	2	12.7	P. M.	E
	5	6.3	A. M.	E
	7	midn.		E
	10	5.7	A. M.	E
	13	11.4	A. M.	E

DIONE CONT.

		h		
Jan.	16	5.0	"	E
	18	10.7	P. M.	E
	21	4.4	"	E
	24	10.1	A. M.	E
	27	3.7	"	E
	29	9.4	P. M.	E

RHEA.

Jan.	2	5.0	P. M.	E
	7	5.4	A. M.	E
	11	5.9	P. M.	E
	16	6.1	A. M.	E
	20	6.5	P. M.	E
	25	6.9	A. M.	E
	29	7.3	P. M.	E

TITAN

Jan.	3	8.2	P. M.	S
	7	3.5	"	E
	11	1.2	"	S
	15	5.0	"	W
	19	7.1	"	S
	23	2.3	"	E
	27	noon		I
	31	3.6	"	W

HYPERION.

Jan.	6	3.9	A. M.	E
	12	12.1	P. M.	I
	17	8.5	"	W
	22	6.3	A. M.	S
	27	10.1	"	E

IAPETUS.

Jan.	20	4.3	P. M.	E
Feb.	7	10.5	"	I

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

R. A. .... $0^h\ 52^m\ 32^s$
Decl .... $+81°\ 17'$
Period .... $2d\ 11^h 50^m$

Jan.	5	1 A. M.
	9	midn.
	14	"
	19	"
	24	11 P. M.
	29	11 "

ALGOL.

R. A. .... $3^h\ 1^m\ 1^s$
Decl .... $+42°\ 32'$
Period .... $2d\ 20^h 49^m$

Jan.	2	2 A. M.
	4	11 P. M.
	7	8 "
	10	5 "
	22	4 A. M.
	25	1 "
	27	10 P. M.
	30	7 "

R. CANIS MAJORIS.

R. A. .... $7^h\ 14^m\ 30^s$
Decl .... $-16°\ 11'$
Period .... $1d\ 3^h\ 16^m$

Jan.	1	9 P. M.
	2	midn.
	4	3 A. M.
	9	7 P. M.
	10	11 "
	12	2 A. M.
	13	5 "
	17	6 P. M.
	18	10 "
	20	1 A. M.
	21	4 "
	26	8 P. M.

R. CANIS MAJ. CONT.

Jan.	27	midn.
	29	3 A. M.
	30	6 "

S CANCRI.

R. A. .... $8^h\ 37^m\ 39^s$
Decl .... $+19°\ 26'$
Period .... $9d\ 11^h\ 38^m$

Jan.	7	4 P. M.
	17	3 A. M.
	26	3 P. M.

S ANTLIÆ.

R. A. .... $9^h\ 27^m\ 30^s$
Decl .... $-28°\ 09'$
Period .... $0d\ 7^h\ 27^m$

Jan.	1	2 A. M.
	2	1 "
	2	midn.
	3	"
	4	11 P. M.
	5	10 "
	6	10 "
	7	9 "
	8	5 A. M.
		8 P. M.
	9	4 A. M.
		8 P. M.
	10	4 A. M.
		7 P. M.
	11	3 A. M.
	12	2 "
	13	2 "
	14	1 "
	14	midn.
	15	"
	16	11 P. M.
	17	10 "

S. ANTLIÆ CONT.

Jan.	18	10 P. M.
	19	5 A. M.
		9 P. M.
	20	5 A. M.
		8 P. M.
	21	4 A. M.
		8 P. M.
	22	3 A. M.
	23	3 "
	24	2 "
	25	1 "
	26	1 "
	26	midn.
	27	11 P. M.
	28	11 "
	29	10 "
	30	9 "
	31	9 "

δ LIBRÆ.

R. A. ....$14^h\ 55^m\ 06^s$
Decl .... $-\ 8°\ 05'$
Period .... $2d 07^h 51^m$

Jan.	2	1 A. M.
	9	1 "
	15	midn.
	22	"
	29	11 P. M.

U. CORONÆ.

R. A .... $15^h\ 13^m\ 43^s$
Decl .... $+32°\ 03'$
Period .... $3d\ 10^h\ 51^m$

Jan.	11	7 A. M.
	18	4 "
	24	2 "
	31	midn.

Numeration of the Asteroids discovered in 1893.—Numbers have recently been assigned to twenty-one of the asteroids discovered by photography this year. Seven others designated 1893 C, D, M, O, U, X, and Y, were not sufficiently observed to permit of determining their elliptic orbits. They therefore receive no numbers. The asteroid 1893 Q has been found to be identical with (104) Klymene, Z with (175) Andromache, AF with (158) Koronis, and AG with (107) Camilla.

The numbers assigned are as follows:

1893 A	Jan. 17	Charlois	354	1893 S	Mar. 17	Charlois	363
B	12	Wolf	352	T	19	"	364
E	20	Charlois	356	V	21	"	365
F	16	Wolf	353	W	21	"	366
G	21	Charlois	355	AA	May 20	"	367
J	Feb. 11	"	357	AB	20	"	368
K	Mar. 8	"	358	AC	July 14	"	370
L	9	"	359	AD	16	"	371
N	11	"	360	AE	5	Borrelly	369
P	11	"	361	AH	Aug. 19	Charlois	372
R	17	"	362				

COMET NOTES.

Comet 1893 II (*b* 1893).—This comet was observed with the 16-inch equatorial at Goodsell Observatory on the morning of Nov. 18. It was very close to the place indicated by Cerulli's ephemeris, published in our last number. It was very faint, about 1′ in diameter, with a slight condensation in the center, so that a fairly good measure could be taken of its position. From. *Astr. Jour.* No. 307 we take the following ephemeris for December:

Gr. M. T.	App. R. A. h m s	Decl. ° ′ ″	Log Δ	Br.
Dec. 5.5	12 44 32.1	−0 08 37		
6.5	44 13.3	0 07 59		
7.5	44 55.9	0 07 13	0.4594	0.078
8.5	43 33.0	0 06 19		
9.5	43 10.8	0 05 16		
10.5	42 47.3	0 04 04		
11.5	42 22.5	0 02 44	0.4554	0.077
12.5	41 56.4	−0 01 16		
13.5	41 28.9	+0 00 22		
14.5	41 00.0	0 02 08		
15.5	40 29.8	0 04 03	0.4511	0.076
16.5	39 58.2	0 06 07		
17.5	39 25.1	0 08 21		
18.5	38 50.5	0 10 43		
19.5	38 14.5	0 13 15	0.4465	0.074
20.5	37 37.0	0 15 56		
21.5	36 58.0	0 18 47		
22.5	36 17.5	0 21 48		
23.5	35 35.4	0 24 58	0.4417	0.073
24.5	34 51.8	0 28 17		
25.5	34 06.6	0 31 47		
26.5	33 19.8	0 35 27		
27.5	32 31.3	0 39 16	0.4367	0.072
28.5	31 41.2	0 43 15		
29.5	30 49.4	0 47 25		
30.5	29 56.0	0 51 45		
31.5	12 29 01.0	+0 56 15	0.4317	0.072

Perturbations and Ephemeris of Comet Holmes.—This body will be in opposition on Jan. 18, 1894, and will be soon in a position favorable for observation. It should be easily found provided its appearance be anything like that which it presented for a considerable time after its discovery, but if, as is quite possible, it has assumed the guise of an *asteroid* of small dimensions, the search for it may be a matter of some difficulty if pursued by the ordinary visual means. A search ephemeris should include the effects of the perturbative action of the planet Jupiter, which action has been very sensible during the time which has elapsed since the date of Holmes' discovery of this remarkable body. I have therefore computed the *special* perturbations of the elliptic elements of the orbit of this body for the dates given in the first column of the following table. I have adopted as the elements osculating at the epoch, those computed by Mr. J. R. Hind, and published in *Astr. Nach.* No. 3152. They are the following:

1892, Nov. 9.5 Gr. M. T.

$$\left.\begin{aligned} M_0 &= 21^\circ\ 12'\ 43''.5 \\ \pi_0 &= 346^\circ\ 16'\ 04''.7 \\ \Omega_0 &= 331^\circ\ 35'\ 38''.2 \\ i_0 &= 20^\circ\ 46'\ 46''.4 \\ \varphi_0 &= 24^\circ\ 06'\ 16''.1 \\ \mu_0 &= 513''.90765 \\ \log a_0 &= 0.5594143 \end{aligned}\right\}\ 1892.0$$

By means of these elements I have computed the following perturbations thereof:

Date.	$\delta \Omega$	δi	$\delta \pi$	$\delta \varphi$	$\delta \mu$	δM
	″	″	″	″	″	″
1892 Nov. 29.5	− 11.32	− 1.56	− 27.90	− 4.10	+ 0.04748	+ 21.74
1893 Jan. 8.5	34.04	3.44	86.82	14.42	0.16094	68.12
Feb. 17.5	55.40	3.84	146.49	25.52	0.28352	126.34
Mch. 29.5	74.42	3.15	203.75	35.92	0.40289	193.07
May 8.5	90.81	− 1.70	256.96	45.10	0.51312	265.57
June 17.5	104.68	+ 0.19	305.70	53.03	0.61244	342.03
July 27.5	116.29	2.35	350.18	59.85	0.70118	421.39
Sept. 5.5	125.95	4.63	390.92	65.77	0.78018	503.11
Oct. 15.5	133.98	6.93	428.58	70.94	0.85082	586.98
Nov. 24.5	140.65	9.21	463.81	75.50	0.91441	672.98
1894 Jan. 3.5	146.21	11.45	497.21	79.50	0.97207	761.17
Feb. 12.5	150.88	13.65	529.31	83.00	1.02483	851.65
Mch. 24.5	154.82	15.80	560.58	85.97	1.07357	944.55
May 3.5	− 158.14	+ 17.92	− 591.28	− 88.42	+ 1.11882	+ 1039.89

Interpolating for 1894, Jan. 1.0, I have found the perturbations for that date to be: $\delta \Omega, -2' \, 25''.97$; $\delta i, +11''.31$; $\delta \pi, -8' \, 15''.16$; $\delta \varphi, -1' \, 19''.27$; $\delta \mu, +0''.96861$; $\delta M, +12' \, 35''.73$. Adding these to the fundamental osculating elements above given, and reducing to the mean equinox of 1894.0, I have obtained the following system:

$$
\begin{array}{l}
\text{1894, Jan. 1.0 Gr. M. T.} \\
\left.\begin{array}{r@{\,}l}
M = & \;\;81^\circ \; 01' \; 15''.67 \\
\pi = & 346^\circ \; 09' \; 30''.00 \\
\Omega = & 331^\circ \; 34' \; 53''.62 \\
i = & \;\;20^\circ \; 46' \; 58''.63 \\
\varphi = & \;\;24^\circ \; 04' \; 56''.83 \\
\mu = & 514''.87626 \\
\log a = & 0.5588691
\end{array}\right\} 1894.0
\end{array}
$$

The equations for the heliocentric rectangular co-ordinates are:

$$x = [9.9937180] \, r \sin(v + 77^\circ \; 44' \; 30''.2)$$
$$y = [9.8766095] \, r \sin(v + 339^\circ \; 07' \; 21''.8)$$
$$z = [9.8323171] \, r \sin(v + 358^\circ \; 23' \; 46''.2)$$

From the data above given I have computed the following ephemeris, the places being referred to the mean equinox of 1894.0:

Greenwich M. T.	R. A.			Decl.			Log r.	Log Δ
	h	m	s	°	′	″		
1894 Jan. 1.5	8	18	40.1	+ 37	07	12.8	0.599202	0.484865
3.5		16	48.3		10	02.5		
5.5		14	54.0		12	25.6		
7.5		12	57.9		14	24.1	0.601326	0.484687
9.5		11	00.2		15	55.4		
11.5		09	01.6		16	58.7		
13.5		07	02.0		17	32.9	0.603426	0.485902
15.5		05	02.2		17	37.8		
17.5		03	02.6		17	12.0		
19.5	8	01	03.7		16	15.6	0.605497	0.488865
21.5	7	59	05.6		14	48.6		
23.5		57	08.8		12	51.1		
25.5		55	13.8		10	23.5	0.607540	0.493189
27.5		53	20.9		07	25.8		
29.5		51	30.4		03	58.9		
31.5		49	42.6		00	02.9	0.609557	0.499118
Feb. 2.5	7	47	57.9	+ 36	55	39.1		

The appearance of this comet will be of interest. Should it be in the similitude of an asteroid of about 12-13 mag. at the time of opposition, it will be reasonable to conclude that it is one of the group of "Minor Planets," and that the truth of the "asteroid collision" hypothesis concerning the origin of this peculiar body is established; but if, on the other hand, it should appear to be of considerable dimensions, or should display the ordinary *indicia* of a comet, viz., a *coma* and a *tail,* we should rightly adjudge the above mentioned hypothesis to be scientifically untenable. SEVERINUS J. CORRIGAN.

St. Paul, Minnesota, Nov. 18, 1893.

Elements and Ephemeris of Comet *c* **1893.**—I send you herewith elements and ephemeris of Comet *c* by Mr. Phillips Isham and myself.

$$\begin{aligned} T &= \text{Sept. } 19.3055 \text{ Berlin M. T.} \\ \Omega &= 174^\circ\ 54'\ 21'' \\ i &= 129\ \ 47\ \ 44 \\ \omega &= 347\ \ 33\ \ 10 \\ \log q &= 9.91033 \end{aligned} \Bigg\} 1893.0$$

Berlin midn.	α app.			δ app.		log Δ
	h	m	s	°	′	
Dec. 1.5	14	03	53	+ 53	15.1	0.119
2.5		08	27	54	23.9	
3.5		13	15	55	32.7	0.118
4.5		18	21	56	41.4	
5.5		23	44	57	50.0	0.117
6.5		29	25	58	58.4	
7.5		35	25	60	06.2	0.118
8.5		41	48	61	13.2	
9.5		48	35	62	19.4	0.119
10.5		55	50	63	24.8	
11.5	15	03	33	64	28.8	0.120
12.5		11	48	65	31.0	
13.5		20	36	66	31.9	0.122
14.5		29	59	67	31.7	
15.5		40	03	68	29.0	0.125
16.5		50	52	69	23.4	
17.5	16	02	26	70	15.3	0.130
18.5		14	47	71	04.4	
19.5		27	57	71	50.2	0.136
20.5		41	59	72	32.4	
21.5		56	50	73	10.7	0.143
22.5	17	12	30	73	45.0	
23.5		28	57	74	14.9	0.149
24.5		46	06	74	40.2	
25.5	18	03	43	75	00.5	0.156
26.5		21	34	75	16.1	
27.5		39	38	75	26.5	0.164
28.5		57	53	75	32.5	
29.5	19	15	53	75	33.8	0.172
30.5		33	28	75	30.7	
31.5		50	33	+ 75	23.3	0.181

J. G. PORTER.

Comet Brooks (*c* **1893**).—This comet, discovered by the writer on Oct. 16, has been observed on every possible occasion, and we have been favored with an unusually fine autumn in this locality—unusual in the great number of clear days and nights. Although the comet had passed perihelion at the time of discovery, it has held its light well, and has been a conspicuous telescopic comet. On the

morning of Oct. 21, 17^h, the comet appeared brighter than at any previous observation. The tail could be easily traced to a distance of $3\frac{1}{2}°$.

Some interesting changes have been noticed in the shape and structure of the tail. Its normal appearance might have been called straight, but on the morning of Oct. 21, 17^h (when the comet appeared at its brightest here), there was a sharp curve in the tail close to the head towards the south, and a faint secondary tail was seen issuing from the head at an angle of 30° to the main tail towards the north.

Bright moonlight then interfered for several days, but when the comet was seen again, on Nov. 4, its tail had assumed its usual straight form with only slight curvature towards the extreme end. On Nov. 9, 17^h, however, another decided and interesting change was detected in the formation of the tail. It was straight for a length of half a degree from the head, where it became forked, the larger portion curving gracefully to the south, the fainter part straight or nearly so, branching to the north, the two branches making an angle with each other of about 25°. The comet on this occasion was bespangled with numerous small stars, forming altogether a most charming telescopic picture.

William R. Brooks.

Smith Observatory, Geneva, N. Y., Nov. 14, 1893.

Photographs of Brooks' Comet.—This comet, which never became visible to the naked eye, and which promised so little in the telescope, has proved to be photographically one of the most remarkable comets yet observed.

I have fortunately secured a splendid series of photographs of the comet on fifteen nights with the Willard lens (6 in. aperture, 31 in. focus).

The exposures have ranged from 30 minutes, at first when the comet was near the horizon, to 185 minutes in the later observations.

Following are the dates of these pictures:

Oct. 18, 20, 21, 22, Nov. 2, 3, 6, 7, 10, 11, 12, 13, 14, 15, 19. On Nov. 15, two negatives were secured each with 90 minutes exposure, to detect any extra rapid changes in the tail.

Though the tail with the 12 in. at its brightest could scarcely be traced 2° the photographs on several occasions showed it for fully 10°—and this at a time when the 12-in. could not trace it 1°.

Besides showing undoubtedly an encounter of the tail on Oct. 21st with some outside and obstructing medium in which the tail was badly shattered, the plates have several times shown independent cometary masses near the extremity of the tail, and one of these at least, I think, can be located accurately enough to determine its orbit.

Rapid and remarkable changes in position angle of the tail are also recorded on these plates.

On several of these dates meteors have left trails on the photographs with the comet, and on the morning of Nov. 14th a magnificent meteor shot across the plate parallel with the comet's tail, leaving a heavy straight trail extremely dense and sharp.

The investigation of these photographs will give us a far better insight into the phenomena of comet tails than we have ever had before.

I hope to be able soon to present some of these remarkable photographs in Astronomy and Astro-Physics.

E. E. Barnard.

Mt. Hamilton, Cal., Nov. 19, 1893.

The November Meteors.—The Leonid meteor radiant was photographed on the mornings of Nov. 14 and 16, with the 2½-inch Darlot lenses of Goodsell Observatory. Two exposures were made on the morning of the 14th, the one from $3^h 50^m$ to 5^h, the other from 5^h to 6^h. The field covered by the plates is 24° in diameter, ζ Leonis being placed in the center. The first plate on the 14th shows one meteor trail near the star $\varkappa$ Leonis. It is about 1° long and points exactly toward the Leonid radiant. It is near the edge of the plate where the definition is poor, so that it is not well shown. The other plates show no trails at all. I saw but few meteors while the exposures were being made, and no very bright ones. The few Leonids I did see moved so swiftly that it is doubtful whether their trails would have been impressed upon the plate had they been within the range of the camera. H. C. W.

November Meteors.—The November meteors were far more abundant this year than I have ever seen them before. Especially were they plentiful on the mornings of November 13, 14, and 15. Many very brilliant ones were seen. One on the morning of the 14th burst just below Coma Berenices. It was nearly as large as the full Moon. On November 15th at $14^h 50^m$ a splendid meteor from Leo shot across the sky and burst between Zeta and Eta Ursæ Majoris. This left a persistent train about 10° long which remained bright and straight for about five minutes—like a slender comet—it then collected into a cloudy mass at the point of explosion. This elongated mass of luminosity remained distinctly visible for half an hour, drifting due east in the meantime about 7°. As I was photographing the comet at this time I could not turn my telescope to it to see how long it remained visible after it had ceased to be seen with the naked eye.

Mt. Hamilton, Nov. 19, 1893. E. E. BARNARD.

NEWS AND NOTES.

George A. Hill, United States Naval Observatory, Washington, D. C., has been appointed to the position of assistant astronomer in the Observatory. He is now at work with the Prime Vertical Transit instrument. He takes the place of A. Hall, Jr., who resigned not long ago to accept the position of director of the Detroit Observatory at Ann Arbor, Michigan.

Professor S. W. Burnham.—At a recent meeting of the Board of Trustees of the University of Chicago, Mr. S. W. Burnham was unanimously elected Professor of Practical Astronomy. The Department of Astronomy is to be congratulated on securing Professor Burnham's eminent services, and the honor which the University authorities have thus done to the cause of Science will be fully appreciated by astronomers everywhere, who will rejoice to learn that Professor Burnham will again have adequate opportunities for continuing his splendid investigations in Double Star Astronomy. It is understood that the micrometrical measurement of Double Stars is one of the principal lines of research contemplated with the great 40-inch refractor of the Yerkes Observatory.

A. G. Winterhalter of the Naval Observatory, Washington, D. C., has our thanks for a corrected copy of the paper read by Dr. Leman of Berlin at the Astronomical Congress in Chicago. It is a very useful paper.

Mr. Tebbutt's Observatory, New South Wales.—We have been favored with a copy of the report of Mr. Tebbutt's Observatory, the peninsula Windsor, New South Wales, Australia, for the year 1892.

The position of this Observatory as noticed in this report is,

$$\text{Longitude} = 10^h\ 3^m\ 20.51^s \text{ East of Greenwich,}$$
$$\text{Latitude} = -33°\ 36'\ 30.8'',$$

a slightly different value from that given in the American Ephemeris and Nautical Almanac for the year 1894. These are claimed to be the old coördinates.

In the first part of this report is given a table of instrumental errors and Chronometer errors and rates for the entire year. Under the head of extra-meridian is found an account of occultations of stars by the Moon observed with 8-inch and 4½-inch equatorials. From 1864 to end of 1892 494 disappearances and 40 reappearances were recorded. Other observations made were upon the phenomena of Jupiter's satellites, conjunction of Mars with ι Aquarii, comets, double stars and variable stars.

Astronomical and Physical Society of Toronto.—At the meeting of the Astronomical Society of Toronto, Canada, Oct. 31st which was unusually well attended, Dr. Larratt W. Smith, Q. C., presided.

Several members were elected

Letters were read from Miss Agnes M. Clerke, Redcliffe Square, London: Mr. J. Ellard Gore, F. R. A. S., M. R. I. A., Ballysodare, Ireland; and Mr. W. F. Denning, Bristol, England, corresponding members of the society. Each enclosed a special paper. Miss Clerke's is entitled, "The Distance of the Nebulæ;" Mr. Gore's, "The Luminiferous Ether:" Mr. Denning's, "The Radiant Point of the Perseid Meteor Shower." The society appreciates the compliment.

Rev. T. E. Espin, F. R. A. S., of Tow Law, England, announced that a red star (observed at R. A. $20^h\ 46'\ 59''$ and N. Decl. 46° 47′) is variable, and is fading.

Four questions respecting magnetism were submitted by Mr. Lindsay.

Mr. A. F. Miller and Mr. Andrew Elvins reported a large sun-spot, visible to the naked eye, which had just passed off the solar disc.

Mr. Arthur Harvey described an aurora observed by himself at Manitowaning on Oct. 7th last.

Messrs. Collins exhibited photographs, including a sharp and clear one of the full Moon.

Dr. J. C. Donaldson of Fergus, Canada, reported a series of lunar observations; also some on close double stars and Jupiter's satellites.

Mr. George E Lumsden stated that at 10 o'clock on the evening of Oct. 10 last a telescope which had shown the Great Red Spot on Jupiter two years ago revealed no trace of it. Seeing was excellent. The place occupied by the Great Red Spot was, at the hour named, on the central meridian of the planet. Mr. Lumsden's inference was that even if the spot is invisible it is still there. On both sides the belts bore the well-known indentations, formed by forcing their way past. He assumed that the spot is variable in color, and that it will again become prominent on Jupiter's disc.

Mr. Harvey presented a small nodule of iron pyrites, given to him as an aerolite. He had been informed that a meteorite weighing several tons which had fallen on Cockburn Island some years ago had been built into a wharf on the island's north side.

Chairman Larratt W. Smith here introduced a pleasant event. The society

desired to honor Mr. George E. Lumsden for his indefatigability as corresponding secretary of the society since its incorporation. Mr. John A. Paterson, M. A., read a eulogistic address from the society to Mr. Lumsden, and presented him and his wife on behalf of the members with a beautiful silver urn and a silver inkstand, suitably engraved. A complimentary poem by Librarian G. G. Pursey and a letter from John A. Copeland were also read. Mr. Lumsden accepted the gifts, and replied in a neat speech. Refreshments were served by the lady members.

JOHN A. COPELAND.

New York Academy of Sciences.—*Section of Astronomy and Physics.—Minutes of the Meeting November 13, 1893*—The meeting was called to order at 8:15 P. M. Professor Rees in the chair. The minutes of the previous meeting were read and approved. The secretary read a paper by Mr. Herman S. Davis, Fellow in Astronomy at Columbia College entitled "Note on Bessel's determination of the relative parallaxes of μ and θ Cassiopeiæ." Mr. Davis had re-reduced the observations of Right Ascension difference of the two stars made by Bessel in the years 1814 to 1816, and printed in Engelmann's "Abhandlungen von F. W. Bessel, vol. 2, p. 215." Employing the Auwers' proper motions of the two stars, and introducing into the Besselian equations a term to allow for differential proper motion, Mr. Davis arrives at the value:

Parallax of μ relative to θ Cassiopeiæ $= + 0''.02 \pm 0''.24$
where Bessel had obtained $- 0\ .12 \pm 0\ .29$

It will be seen that the new reduction diminishes materially the probable error of the result, in spite of the fact that the introduction of the proper motion term into the parallax equations has lessened the weight of the determination of the parallax itself. Mr. Davis' result is in very close, though perhaps accidental, accord with that derived from Mr. Rutherfurd's photographic measures, which was $+ 0''.04$. (Annals N. Y. Academy, Vol. VIII, p. 11).

Professor William Hallock read a paper on "The Theory of Geysers," in which he described his researches upon the geysers of the Yellowstone Park, and explained their action. A glass model geyser was exhibited, in which the internal arrangement and action were plainly shown. Steam was supplied to the model from a small copper boiler, and it reproduced very successfully the remarkably regular periodical eruptions which in Nature are caused by the supply of steam from the interior heated strata of the earth.

After some remarks by various persons the Section adjourned.

HAROLD JACOBY, Secretary of Section.

The Chicago Academy of Sciences—Section of Mathematics and Astronomy—Nov. 7.—Professor S. W. Burnham, Recorder of the Academy of Sciences, reported to the Section that the Board of Supervisors of Santa Clara County, California, had decided to present the astronomical and other photographs made at the Lick Observatory for the exhibit of Santa Clara County at the World's Columbian Exposition, to the Chicago Academy of Sciences for permanent exhibition in their magnificent building now nearly completed in Lincoln Park. These transparencies include some of the beautiful star and comet pictures made by Professor Barnard and a choice section of views about Mt. Hamilton. They will be exhibited at the Mid-Winter Exposition at San Francisco, and then returned to Chicago as a gift to the Academy from the County of Santa Clara.

Dr. T. J. J. See of the University of Chicago read a paper on "The Different Methods of Determining the Solar Parallax, and especially on the Method depending upon the Constant of Aberration." The author reviewed the different methods employed by astronomers for finding the distance of the Sun, and gave a résumé of the results obtained in recent investigations of the subject. He pointed

out the close agreement of Dr. Gill's parallaxes derived from the observations of Mars and Victoria and Sappho with the parallaxes deduced from the constants of aberration determined by Nyrèn, Comstock, Küstner, and Peters, and concluded that the solar parallax will almost certainly lie between 8″.78 and 8″.81, with the chances in favor of 8″.795, which is approximately a mean of the best recent results. Attention was called to Laplace's use of the value 8″.8 in the *Mecanique Celeste* a century ago, and the opinion was expressed that the value 8″.80 might now be safely adopted in the astronomical ephemerides.

Professor Hough pointed out the influence of systematic errors in vitiating results and remarked that the true value of the solar parallax could be obtained only by many separate and independent determinations. Dr. Crew made some remarks on Professor Michelson's determination of the velocity of light, which he considered very exact, and said the existence of aberration showed that the Earth did not carry the ether with it, as some physicists had at one time been led to suppose. Professor Burnham called attention to the tendency of astronomers to over-estimate the accuracy of their results, and said that it was unsafe to trust too implicitly such values even if supported by very small probable errors. It was generally agreed by the speakers that any value of the solar parallax larger than 8″.81 must be regarded as improbable, and that the results deduced from the transit of Venus, even if the observations had been discussed with the utmost rigor, were relatively of no value, as the phenomenon of irradiation known as the "black drop," rendered the *method* worthless. The opposition of Mars and small planets and the constant of aberration were regarded as the only methods at present available for improving our knowledge of the astronomical unit. Adjourned. T. J. J. SEE, Recorder.

BOOK NOTICE

An Astronomical Glossary, or Dictionary of Terms used in Astronomy, with Tables of Data and Lists of Remarkable and Interesting Celestial Objects. By J. E. Gore, F. R. A. S. London, England: Messrs. Crosby, Lockwood & Son, 7 Stationers Hall Court, Ludgate Hill. 1893, pp. 139.

This small book gives explanations of all the terms and names generally used in books on astronomy, and is therefore intended as a reference book both for the beginner and the advanced student. The part called the glossary covers 116 pages, with titles in heavy-faced type, and arranged in alphabetical order. The explanations under these titles are full or complete, according as the title is important. We give two specimens that our readers may judge of the character of them for themselves:

Aberration of Light. An apparent displacement in the position of the stars due to the effect of the Earth's motion in its orbit round the Sun, combined with the progressive motion of light. The result is that "a star is displaced by aberration along a great circle joining its true place to the point on the celestial sphere toward which the Earth is moving." (Barlow & Bryan's Mathematical Astronomy, p. 289.) The amount of aberration is a maximum for stars lying in the direction at right angles to that of the Earth's motion. This is known as the "constant of aberration," and its value in seconds of arc is 206,265 multiplied by the velocity of the Earth, and divided by the velocity of light, or about 20.5″. The motion of the Earth on its axis produces a small aberration called the Diurnal aberration, but the co-efficient of this is very small—only 0.32″—and almost imperceptible in observations. For a star on the celestial equator, viewed from the Earth's equator, the time of transit would be retarded by Diurnal Aberration by only one-fiftieth of a second which could be hardly observed.

Scintillation. A name sometimes applied to the twinkling of the stars.

Besides the part devoted to the glossary there are a number of tables giving useful data pertaining to the Earth, Moon, Sun, Mercury, Venus, Minor Planets, Jupiter, Saturn, Saturn's Rings and Neptune; the Satellites of the outer planets, remarkable red stars, variable stars and binary stars for which orbits have been computed. For so small a book it is a desirable one for reference.

Errata.—Page 732, line 12, for 4th quadrant read 3rd quadrant. Page 888, line 9 from bottom, for prndulum read pendulum; line 7 from bottom for dice read disc.

PUBLISHER'S NOTICES.

The subscription price to ASTRONOMY AND ASTRO-PHYSICS in the United States and Canada is $4.00 per year in advance. For foreign countries it is £1 or 20.50 marks per year, in advance. Recent increase in price to foreign subscribers is due to increase of postage because of enlarged size during the year 1892. Messrs. Wesley & Son, 28 Essex Street, Strand, London, are authorized to receive subscriptions. Payment should be made in postal notes or orders or bank drafts.

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For information of correspondents, the names and addresses of the associate editors of ASTRO-PHYSICS are given as follows:—

James E. Keeler, Observatory, Allegheny, Pa.; Henry Crew, Northwestern University, Evanston, Ill.; Jos. S. Ames, Johns Hopkins University, Baltimore, Md.

All matter or correspondence relating to General Astronomy, remittances, subscriptions and advertising should be sent to Wm. W. Payne, Publisher and Proprietor of ASTRONOMY AND ASTRO-PHYSICS, Goodsell Observatory of Carleton College, Northfield, Minn.; and the Associate Editors for General Astronomy are: S. W. Burnham, Government Building, Chicago Ill.; E. E. Barnard, Lick Observatory, Mt. Hamilton, Cal., and H. C. Wilson, Goodsell Observatory, Northfield, Minn.

Manuscript for publication should be written on one side of the paper only and *special care should be taken to write proper names and all foreign names plainly*. All drawings for publication should be *smoothly* and *carefully* made, in *India Ink* with lettering well done, because such figures are copied exactly by the process of engraving now used. If drawings are made about double the size intended for the printed page, better effect will be secured in engraving than if the copy is less in size. It is requested that manuscript in French or German be typewritten. If requested by the authors when articles are sent for publication, *twenty-five* reprint copies, in covers, will be furnished free of charge. A greater number of reprints of articles can be had if desired, at reasonable rates.

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